

Board characteristics and firm Performance: The mediating role of Open Innovation

Practices

ABSTRACT

Research on board capital has consistently proven its importance for firm performance. However, the impact of board capital and renewing board members on open innovation (OI) practice is little explored. “Board capital” is the total resources that are embedded within, accessible through, and obtained from the network of relationships possessed by Board members. Thus, using the Board Human and Social Capital theory from the perspective of the Board of Directors, this study examines the board's role in a firm's OI practice and explores how OI practices mediate the effect of the board on a firm's financial performance. Empirical evidence using 2859 firm-years for Indian high-tech firms from 2013 to 2022 shows that board capital and renewal with new members are related to firms' financial performance. OI practice partially mediates the relationship. This paper illustrates several implications and provides scope for future research on the board's tasks and open innovation paradigm.

Keywords: *open innovation, board renewal, board human and social capital*

1. INTRODUCTION:

Acquiring external knowledge is critical for firms' innovation activities (Laursen & Salter, 2006), and the Board of Directors (BOD), with their various intellectual capital, helps achieve this. The intellectual capital comprises structural, human, and societal capital (Vitolla et al., 2020), within which board capital refers to the combined human and social capital possessed by the board of directors (Hillman & Dalziel, 2003). It represents the board's capacity to contribute resources to the firm. Scholars have long been interested in understanding the impact of board characteristics on firm performance, which is widely studied like gender (Adams et al., 2023), size (Song et al., 2020), culture (Naqshbandi & Tabche, 2018), board continuity (Wincent et al., 2009), and others, in the context of innovation and firm performance. However, with the growing interest in Open innovation (OI) practices among firms (Chesbrough, 2003), there is an increased interest in understanding how the board affects OI practice. Moreover, various OI practices depend on the level of integration with outside partners. Firms can use modes like crowdsourcing, hackathons, license agreements, corporate venture capital (CVC) investment, Alliances, Joint ventures (JV), and mergers and acquisitions (M&A) for knowledge and ideas acquisition from outside firms. Wynarczyk et al. (2013) state that it is part of the board's mandate to promote OI practice and board representation is coupled with OI projects, which are positively correlated (Adams et al., 2023). OI is achieved by deliberately exchanging knowledge to speed up internal innovation and broaden the adoption of inventions (Chesbrough, 2003, 2006). Board members, via their experience, competence, and inherent qualities, as described by Nielsen and Huse (2010), can manage various stakeholders and OI projects effectively. Further, senior management should be appointed by at least three non-executive directors, two of whom must be independent. The chairperson must also be an independent director (Companies Act, 2013) and have an ideal balance

between executive and non-executive directors on the company's board of directors, with non-executive members making up at least half of the board (SEBI corporate governance – clause 49). Diversity, attendance, and directorship have all been the subject of several studies, while board education and experience have gotten less attention from academic and empirical studies. Building on the earlier studies (Jermias & Gani, 2014; Shen, 2019; Wincent et al., 2013), our study aims to bridge this gap in the existing research on OI using board capital theory and exploring the role of board capital and renewing the board members on firm performance. Using 2865 firm-years between 2013 and 2022 of Indian high-tech listed firms in NSE, our analysis shows that various dimensions of board antecedents (board human capital, board social capital, and new board renewal) impact highly integrated OI practices like Alliance, JV and M&A, and OI practice mediates the relationship between board antecedents and firm performance. OI practice partially mediates the relationship between board capital and the firm's financial outcome. This essay examines the significance of BODs in OI collaborations, a neglected area of study in the past (Chesbrough, 2004). The presence of persons in top management positions is crucial in bridging the perceived disparity between the theory and practice of OI (West et al., 2014). Thus, there is still a need for a current study to concentrate on the effect BODs can have on OI, particularly in emerging nations like India, where OI may be a relatively new occurrence.

We analyzed the strategies and actions taken by the company's management and organization during this change by addressing how external sources of innovation can enter the firm through the upper echelons and various OI practices. Thus, practitioners can involve the board in improving their OI practices. These findings have significant significance for both academic theory and practical application. Ultimately, the last section of the paper delves into the conclusions drawn from the study and explores potential directions for future research.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW:

2.1 Board capital and board renewal:

Intellectual capital is increasingly recognized as the primary resource for a firm's innovation (Swartz & Firer, 2005), which is of three categories -- structural, human, and societal (Vitolla et al., 2020). Human intellectual capital refers to individuals' collective experience, knowledge, skills, and networks, which help in better decision-making (Becker, 1964; Coleman, 1988; Jeremias & Gani, 2014). Hillman and Dalziel (2003) first presented the concept of board capital as the combined value of the human and social capital the board of directors possessed. Board human capital is categorized into two distinct forms - educational knowledge and industry experience (Kor & Sundaramurthy, 2009). In contrast, social capital pertains to directors' previous collaborative experiences within the main board, and external social capital relates to the board's affiliations with other firms through external directors (Tian et al., 2011). An individual's social capital is defined by Nahapiet and Ghoshal (1998) as the total resources, both actual and potential, that are embedded within, accessible through, and obtained from the network of relationships an individual possesses (Haynes & Hillman, 2010). The components of board capital antecedents include board renewal (Hoppmann et al., 2019), board experience (Tian et al., 2013; Cowden et al., 2015), board knowledge (Fernandez et al., 2020), and board interlocking (Xia et al., 2023). Pfeffer and Salancik (2015) argue that when a board chooses a director, it is important for the director to have connections with external organizations. Additionally, they suggest that these new directors can bring new ideas to the board based on their unique knowledge and experiences.

2.1.1 Board renewal with new member (NBR)

The capacity of well-established companies to rejuvenate and expand their internal resources and competencies is crucial in gaining a competitive edge (Agarwal & Helfat, 2009; Eisenhardt & Martin, 2000; Teece et al., 1997). Firms must leverage the knowledge and skills of people outside their organization, as not all experts work for the same company. Thus, firms are increasingly partnering with specialists from other industry sectors to develop and seek new sources of competitive advantage (Porter & Kramer, 2011; Roszkowska-Menkes, 2018). Effective governance is influenced by board self-evaluation and self-reconfiguration (Hoppmann et al., 2019). A board can participate in self-reconfiguration if it has determined to improve its capacity to implement outside-in practice (Hoppmann et al., 2019). Board renewals periodically refresh board membership to ensure that the board remains aligned with the organization's strategic goals by bringing in diverse members with diverse backgrounds and experiences. In their study, Kim and Cannella (2008) examine the influence of social capital on selecting new directors, the makeup of boards, and the efficacy of boards. Prior research has examined many facets of boards. Our study theorizes how board renewal can bring new perspectives, knowledge, and connections and affect firm innovativeness and performance. This can be done by adopting a board capital approach.

2.1.2 Board Human Capital (Experience and Knowledge)

The two main components of board capital are human (BHC) and social (BSC). The information, abilities, and experiences that board members have gained through their education and varying industry and environmental exposure make up their human capital (Ambulkar et al., 2022).

The term "firm-specific human capital of outside directors" refers to the knowledge and familiarity that these individuals possess regarding the specific company on whose board they serve. On the other hand, "industry-specific human capital" refers to the knowledge, abilities, and experiences

that these individuals acquire from working in other companies within the same industry as the focal firm (Hillman & Dalziel, 2003; Kor & Sundaramurthy, 2009). An essential aspect to consider is examining the firm- and industry-specific human capital outside directors possess. This is crucial since directors who lack human capital typically struggle to supervise and provide guidance to top management effectively. (Kor & Sundaramurthy, 2009; Larcker & Tayan, 2020). Without sufficient human capital, directors are unlikely to identify instances of top management opportunism (Kor & Sundaramurthy, 2009) and offer valuable guidance and advice to top managers regarding R&D investments (Dalziel et al., 2011). Experienced board members are crucial human capital assets because they offer the company a wealth of collected experience, skills, and information that can be useful in OI practice and help the company perform better (Habtoor, 2022). Human capital within a company can significantly impact the transmission and accumulation of knowledge from external sources, leading to innovative outcomes (Vrande et al., 2009). Incorporating a measure of external human capital can enhance our comprehension of how these resources interact with external technology sourcing. "Hiring Qualified Personnel" refers to selecting employees with relevant professional experience and commercial acumen in the technical sector (Diaz & Perez, 2014). According to Wu (2008), directors hired from internal organizations who are engaged within the organization generally possess more knowledge about the activities happening inside the firm than outside directors. As a result, the external knowledge of internal directors becomes less active compared to those hired from outside. Directors accumulate more human capital, enabling them to identify instances of top management opportunism more effectively, thus enhancing their ability to fulfil their monitoring responsibilities (Kor & Sundaramurthy, 2009). This study investigates outside directors' human capital, including the knowledge and skills particular to individual firms and industries.

2.1.3 Board Social Capital (Interlocks)

Board members' involvement can improve corporate innovation, which belongs to industry association networks composed of business and technology associations (Qiao et al., 2014). By choosing the best partners and determining the intensity of the connections, board members may increase their inclination to cooperate (Santoro et al., 2018). According to Capital theory, board composition affects a firm's innovation ability (Kim & Cannella, 2008). People with high external social capital frequently serve as boundary spanners, connecting their organizations to important external resources or information. Social capital refers to director candidates' connections with individuals within and without the company. Board capital is a crucial foundation for businesses to access essential resources internally and externally (Fernandez et al., 2021). BOD networks provide external resources, social capital, and control advantages, reducing information asymmetries in corporate decision-making and enhancing the quality of corporate decisions. The BODs network, consisting of BODs serving in several organizations, is a significant representation of inter-firm network ties. It has gained growing academic interest as a means of social capital and informal institutions. BODs strategically positioned in the network receive greater attention from external stakeholders. The capacity of network participants to comprehend information is a fundamental element of social capital (Wal et al., 2016). According to social capital theory, board social capital encompasses not just the personal connections of individual directors but also their social resemblance to others. Both Kim and Cannella (2008) contend that social capital is not inherent in individuals but resides in their connections to others.

2.2 Open Innovation (OI) Practice:

According to Chesbrough (2003), companies may need purposeful inflows and outflows of knowledge (Chesbrough, 2006) and use external ideas and resources (Huang et al., 2012) as they

work to advance their technology or knowledge base and speed up internal innovation. They become more reliant on various outside sources of information (Laursen & Salter, 2006; Cassiman & Veugelers, 2002). Lu & Chesbrough (2022) propose that OI practice encompasses several practices, including customer involvement, partnership and joint venture activities (Wynarczyk et al., 2013), partial technology mergers and acquisitions (M&A) (Yakis-Douglas et al., 2017), industry-academia collaboration (Bogers et al., 2018), contracts and IP licensing (Schaper et al., 2023), and bilateral transactional activities. Strategic M&A and cooperative alliances play a vital role in industries that require significant capital and knowledge and rely on rapidly advancing technologies (Hoffmann & Schlosser, 2001).

2.3 Board Role in Open Innovation (OI) Practice:

The BOD is the top governing authority of any organization. Apart from other BOD responsibilities, they make strategic decisions so organizations remain open to external collaborations (Chesbrough, 2003). They can help create appropriate governance structures and coordination mechanisms to manage external relationships (Wincent et al., 2009). They can create a supportive environment for OI initiatives (Teece, 2007). According to Koellinger (2008), board members at innovative firms tend to prioritize individuals with prior board experience to enhance the firm's potential for innovation. Board members who deeply understand the technology or any resource that needs to be sourced from outside (Boudreau & Lakhani, 2016) can improve OI practice, identify new opportunities, and develop strategic partnerships. Board members focus on cross-border knowledge flows involving external collaborators and the focused business. According to Rubera et al. (2016), board members should be better able to access ideas, technologies, and products or services if they have strong technological skills. For open inbound search approaches for innovation, new board members with stronger technical and information-

sourcing skills must be appointed (Pintado & Bianchi, 2020). Thus, boards with prior experience in innovation and technology and who served earlier organizations can enhance OI practice. Further, the resources and knowledge benefits derived from a BOD network can decrease the amount of risk and enhance the motivation of managers to engage in open innovation. A firm with high centrality in the BOD network can have superior access to information and resources (Shropshire, 2010). The BODs network facilitates the mitigation of risks associated with open innovation and ensures the cultivation of open innovation practices within firms. Previous research has examined how board interlocks influence the formation of joint ventures and strategic alliances (Gulati et al., 2009), influence strategic decision-making (Carpenter & Westphal, 2001), and lastly, foster the innovation process (Hoskisson et al., 2002). Board involvement can help improve collaboration and partnership with other organizations and research labs, enhancing OI. Similarly, renewing the board by bringing external members may be appropriate if the organization seeks to access new skill sets, expertise and new perspectives and knowledge to enhance OI practice (Obradovic et al., 2021). According to Chesbrough (2003, 2006), external interlocking is a significant factor regularly linked to OI. It comprises all actions necessary to establish and maintain relationships with individuals and groups outside sources of social capital (Vrande et al., 2009). Arias-Pérez et al. (2022) and Greco et al. (2019) have demonstrated that companies without strong internal and inter-organizational networks among top-level executives negatively impact the sharing, adoption, and success of new open innovation (OI) concepts.

Recent studies indicate that the performance of Board members as Open Innovation (OI) leaders depends on the interaction of multiple elements. Nevertheless, the literature on OI leadership tends to underestimate the intricacies involved. Currently, there is a lack of research on the processes and factors that influence the emergence and success of Board members as leaders in Open

Innovation (OI). Faridian (2023) examines how entrepreneurial leadership influences the coordination of different resource areas to achieve successful value generation and acquisition in open innovation (OI). The role of boards as Open Innovation (OI) leaders is to create an atmosphere that fosters different motivational motivations among network members in the input domain. According to Xu & Xu (2023), the BODs network is a crucial means for enterprises to acquire external knowledge, serving as a resource foundation for open innovation. We use the structurally diverse board composition characteristics (percentage of insiders, outsiders, and independent board members), board renewal, and interlock or collaboration to examine the relationship between OI and these attributes, which we will discuss further. Thus, we can synthesize our first hypothesis as follows:

Hypothesis 1a: Renewing board members from outside organizations impacts OI.

Hypothesis 1b: Board members with Human capital (experience and knowledge in technology or innovation) impact OI.

Hypothesis 1c: Board members with social capital (interlocks or external connections) impact OI.

2.4 Board Capital (Social & Human), New Board renewal and firm performance

The board's role is widely acknowledged as crucial in providing governance mechanisms. Extensive research has focused on understanding their function on firm performance (Dalton & Dalton, 2011). Several research studies in this field have examined the impact of boards' external social capital on firm performance (Kim, 2005; Kim & Cannella, 2008; Kor & Sundaramurthy, 2009). Various research has presented different perspectives on the connections between external social capital and company performance. Some say these associations are positive (Kim & Cannella, 2008), while others suggest a curved pattern, namely an inverted U-form (Kor &

Sundaramurthy, 2009). Another study proposes a negative relationship (Goerzen & Beamish, 2005). There is vast research on how directors' demographic, human, and social capital characteristics influence board effectiveness and corporate performance. Empirical research shows a positive association between business success and director education level (Kim & Lim, 2010; Nguyen et al., 2015). There is a dearth of research on the importance of board characteristics, notably board education and experience; thus, this study seeks to fill the gap in the previous literature. Separate board members can provide valuable resources such as advice and counsel, legitimacy, information links, and preferred access to external commitments and support. As a result, the board chair's identity and ability (or lack thereof) to supply these resources may substantially impact the firm's performance (Withers & Fitza, 2017). Krause and Semadeni (2013) discovered that a board chairman can provide independent scrutiny that improves subsequent business performance. Thus, we can synthesize our first hypothesis as follows:

Hypothesis 2a: Renewing board members from outside organizations impacts Firm Performance.

Hypothesis 2b: Board members with Human Capital (experience and knowledge in technology or innovation) can impact Firm Performance.

Hypothesis 2c: Board members with social capital (interlock or external connections) can impact Firm Performance.

2.5 Board Capital (Social & Human), New Board renewal and firm performance and the mediating effect of OI practice.

The impact of the board composition on company outcomes may not be consistent but change over time following the board's renewal (Maida & Weber, 2022). Efforts to renew the board may naturally bring about a greater variety of perspectives (Li & Wahid, 2018), linked to improved

firm performance (Aman & Nguyen, 2008). Several studies (Li & Wahid, 2018; Maida & Weber, 2022; Hoppmann et al., 2019; Elms & Pugliese, 2023) underlined the effect of board renewal on firm performance. The influence of renewing board members from outside the institution and the effects that can be had by including outsiders in the board group have not gotten as much attention in empirical studies across several nations. By examining specific aspects of corporate governance, such as the function of the board of directors, we can gain valuable insights into India's adoption of OI principles. The renewal rates at which network boards can significantly impact inventive performance improvement in network member firms (Wincent et al., 2009); thus, renewing the board is crucial to support open innovation practices.

Medina et al. (2011) assert that social capital and human resources management techniques further augment human capital's direct and favourable impact on company innovativeness. Human and social capital is the foundation of absorptive ability and plays an increasingly important role in the success of open innovation, according to Martínez et al. (2020). The Board capital theory demonstrates that the board is crucial in advising managers on practice by equipping them with information, resources, and guidance (Hillman & Dalziel, 2003; Pfeffer & Salancik, 2015). According to Board capital theory, the characteristics (Jermias & Gani, 2014) and backgrounds (Rose, 2007) of the board members influence firms' outcomes. Board members should only be chosen based on their education and experience, particularly in technology, to ensure improved firm performance (Habtoor, 2022).

Beckman et al. (2014) contend that having many relationships with different partners accelerates creating a varied portfolio of alliances. Forming partnerships with other firms fosters learning and the integration of complementary competencies (Enkel & Sagmeister, 2020). This, in turn, expedites the achievement of significant firm performance. Board interlocks occur when directors

of a company simultaneously hold numerous director positions in different companies, creating connections across corporations (Song et al., 2021). Previous research has examined how board interlocks affect firm performance (Dalton et al., 1999; Larcker et al., 2013). Several studies have examined the complex connection between board interlocks and firm performance across different industries. However, the empirical results have been equivocal, combining positive and negative findings (Devos et al., 2009; Drees; Heugens, 2013).

Despite the work of OI theorists like von Briel and Recker (2017) and Brunswicker and Chesbrough (2018), previous studies have not explored how OI practice mediates the relationship between board capital and firm financial performance in emerging economies like India, where OI may be a novel occurrence. West & Bogers (2013) and Faems et al. (2010) evaluated the OI literature and discovered that more research is needed to identify mediators in this relationship. Although the impacts of coupled, inbound, and outward OI on firm performance have been investigated in large enterprises and SMEs (Rass et al., 2013; Wang et al., 2015), the individual factors and moderators that support the development of OI have been disregarded up until now. Renewing board members with external members who have diverse knowledge and interlocks helps manage the OI practices of a firm. Specific knowledge, skills, and relevant industry experience may help sourcing, sensing, and implementing better OI strategies. Board connections and interlocks help flow knowledge, ideas, R&D solutions, and resources through OI practices. Thus, minimizing internal R&D costs can help improve firm performance. We can synthesize our hypothesis as follows:

Hypothesis 3a: The effect of board renewal on firm performance is mediated through OI practice.

Hypothesis 3b: The effect of board experience and knowledge on firm performance is mediated through OI practice.

Hypothesis 3c: The effect of board interlocks on firm performance is mediated through OI practice.

3. THEORETICAL FRAMEWORK

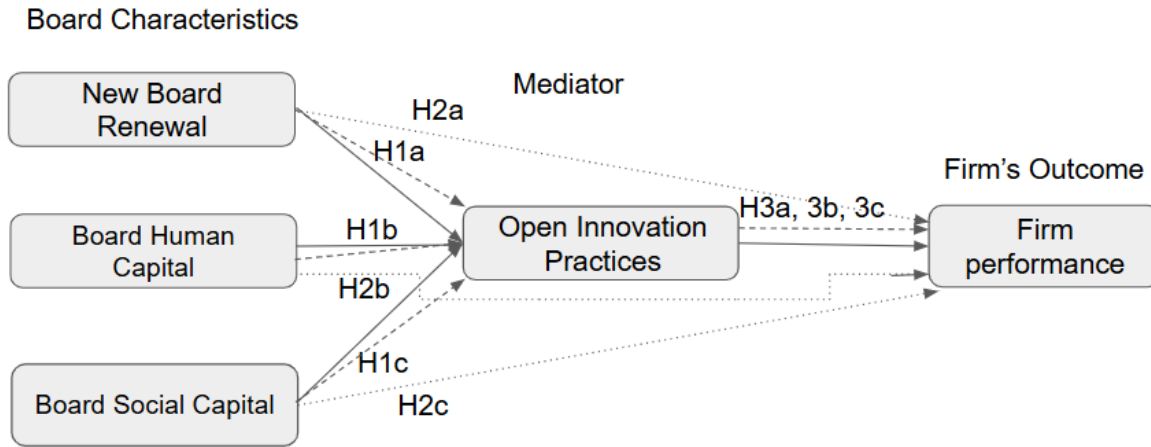


Figure 1: A model framework of Board Characteristics on OI practice and Firm Performance (FP)

4. METHODOLOGY

4.1 Data and Samples:

This study used a panel dataset of an emerging economy—Indian high-tech industries listed in NSE, as OI practices are prevalent in high-tech sectors. The timeline of this study is 2013-2022. As the Companies Act 2013 mandates some changes in the board configurations, we decided to consider 2013 as the beginning year of our observation. India is a manufacturing hub for technological innovation and is ranked 40th in the world for innovation. The Indian government has chosen innovation-led growth and entrepreneurial development practices to boost employment and hasten economic growth (Abhyankar, 2014). According to Kumar and Russell (2002), India and other emerging economies are technologically behind developed economies. OI is crucial in

helping Indian businesses build their technological capacities. We gathered data from multiple sources, including CMIE Prowess (Helmets et al., 2017). NSE Prime Infobase databases (Biswas & Kumar, 2022), which provide board characteristics and firm-level operational data, Thomson SDC Platinum (Shukla et al., 2023) and Refinitiv Eikon (Adams et al., 2023) contain detailed information about JVs, alliances, and M&A data used to measure OI practice.

The study aggregated the dataset by matching based on the companies' NIC codes. For sampling purposes, we have taken a sample size of 20815 firm years from timeline 2013-2022 for both NSE and BSE listed firms. Further, based on the availability of FP measures, we took only 19647 firm years. To calculate OI practice, we removed terminated alliances (<5 years of productive life from the date of formation); thus, the data was reduced from 4961 to 4928. After merging the OI practice data with the final data, 4763 firm years were obtained. Finally, we have selected only high-tech firms because these industries follow OI practice, which gives a total of 413 firms or 2864 firm years based on the Lists of high-tech sectors, which includes Drugs & pharmaceuticals, Computers, peripherals & storage devices, other automobile ancillaries, Diversified automobile, other electronics, Consumer electronics, ITES, Computer software and chemicals (excluding fertilizers) (Department of Science and Technology report, 2023). Further, we dropped the financial institution, which gives a total of 2859 firm years.

4.2 Variables and Measures:

4.2.1 Dependent Variable

The study operationalized the firm's financial performance as a measure of return on sales (ROS) (Hendricks & Singhal, 2001). Because traditional performance assessments in related businesses frequently emphasize profit as a percentage of sales, choosing ROS is compatible with our conceptual framework (Zhang, 2005). The ROS metric enables the analysis of operating profit

margin variations across firms that result from external OI initiatives. We also used Tobin Q, which is calculated by dividing the (MVE + debt) by the book value of assets. For robustness measures, we use “EBIT divided by total assets” to calculate ROA, while EBIT divided by total shareholders' equity is used to calculate ROE. The Refinitiv Eikon and CMIE Prowess databases are used to compile the data.

4.2.2 Independent Variables

New Board renewal measures – We used the proxy measure of the percentage of new board members (independent and non-executive directors) measured annually (Wincent et al., 2013) from the NSE prime database.

Board Human Capital - The Board's previous industry expertise includes a specialized understanding of competition, R&D, regulatory hurdles, and the necessary focus (Barrett et al., 2021). The functional background refers to the expertise acquired by working in several functional areas (Chesbrough, 2010). Looking at their brief profiles, skills, and experience (in technology and innovation roles such as R&D, product development, engineering, or entrepreneurship) (Barker & Mueller, 2002), educational background (degree in engineering, information technology, or computer science), and experience serving on the board of technology or innovation-focused companies (Bogers et al., 2018). Thus, we included the discrete variable BODs education and experience taken from the NSE Prime Infobase database.

Board Social Capital - According to Hoffman et al. (1998) and Huang et al. (2012), the entrepreneurial Board member is involved in inter-organizational networks, including both informal (personal networks) and formal (professional networks). We measured the board interlocks as the number of organizations the externally appointed board members are affiliated with (Boh et al., 2020) and the data collected from the NSE Prime InfoBase and CMIE Prowess

Database. We lag all independent variables by two years and control variables by a year (Vafeas, 1999; Walls & Hoffman, 2013; Kor, 2006).

4.2.3 Mediator Variables –

We categorize the OI practices in terms of Equity and non-equity technology OI practices. In equity technology OI practice, partnership companies exchange ownership stakes, while non-equity technology OI practices involve collaboration between companies without exchanging ownership stakes (Globerman & Nielsen, 2007). Companies have multiple options to acquire such knowledge from other sources through Alliances, licensing, and acquisitions (Cassiman & Veugelers, 2006), crowd-sourcing (Leimeister et al., 2009) and innovation tournaments (Boudreau et al., 2011). These channels are generally categorized as open innovation (Chesbrough, 2006). Firms initially utilize intermediate-level integration methods, such as networking, alliances, and CVC, while implementing inbound open innovation (Chesbrough & Schwartz, 2007; Enkel & Gassmann, 2010; Pinarello et al., 2022). When a firm identifies a new opportunity that aligns closely with its primary business, it tends to rely on procedures with a high level of integration for sensing. Other companies often adopt highly integrated processes to fully capitalize on the outcomes of their sensing objectives, which can be done better through strategic alliances or mergers and acquisitions (M&As) (Vrande et al., 2011).

For our study, we are considering a highly integrated channel of equity technology transfer like “strategic alliances”, JV, and “Partial M&A” (Gilsing et al., 2016; Mawson & Brown, 2016; Yakis-Douglas et al., 2017) pursued by the companies during the fiscal year, as documented in the SDC platinum database, and furnished supporting proof, we coded as the summed up of both the practices. We tracked each firm's OI partnership formation from its first to its final year of participation. Although ties usually endure over a year, termination dates are rarely published. To

avoid this issue, we followed previous studies and assumed a five-year productive life span (Gulati, 1995; Lavie & Miller, 2008; Vasudeva et al., 2013). Because alliance termination dates are not well documented, and to avoid bias caused by the dissolution of alliances among more prominent firms, which is more likely to be reported in the media, we assumed a five-year life span for each alliance when building the alliance networks (Schilling & Phelps, 2007) through which firms engage in OI. Based on this idea, alliance ages ranged from 0 to 5 years (Vasudeva et al., 2013). Finally, we added the total number of “alliance” and “partial M&A” practices to craft the OI practice variable.

4.2.4 Control Variables - Following prior studies, we controlled for – the firm's size (Cohen & Klepper, 1996). We calculated the firm's size as the logarithm of its total assets (Zhang et al., 2022). We calculated firm age as the total number of years from the date of establishment (Grimaldi et al., 2021). The human capital investment (Vaizey & Schultz, 1972) is calculated as the log (employee’s total compensation).

According to Shou et al. (2021), we determined financial leverage by dividing a company's total debt by its entire assets (Lu et al., 2022). We calculated R&D intensity as the ratio of R&D costs divided by revenues (Lu et al., 2022). We measure the board size as the number of board members on the interlock board. We measured the variable by dividing the number of board meetings publicly reported by the total months each year. With the CMIE prowess data and taking a one-year lag, we have controlled for board compensation since motivation directly impacts OI practice (Thorgren et al., 2010). It is calculated as the log of total remuneration given to board members each year.

We considered industry effects in this study (Wang et al., 2015) since various high-tech industries may employ various knowledge and technology techniques. We incorporated year-dummy

variables to account for industry shocks over the analyzed period (Hu et al., 2015). The list of variables used in our study is given in Table 7 - Appendix.

5. ANALYSIS AND RESULTS

Insert Table 1 about here.

Table 1 displays the descriptive analysis, and Table 2 represents the pairwise correlation between the different variables. Tables 3 and 4 show that the external board renewal, experience, knowledge, and interlock positively correlate with OI practice (Coeff = 0.0495, 0.1610, 0.1429; p-value = 0.016, 0.00, 0.00). With firm performance (Tobin Q), board interlock shows a negative relationship (Coeff = -0.0801, p-value = 0.0012), board experience and knowledge have a positive relationship with ROA (Coeff = 0.0565, p-value = 0.0123), and board renewal has a negative relationship with ROE (Coeff = -0.0525, p-value = 0.015). All the results are significant. All pairwise correlation coefficients for independent, mediator, and control variables are less than 0.51, and the highest VIF value is 3.79, well under 10, which means no multicollinearity in our measurements. We found that time-fixed effects are required for the fixed effects model. We also checked for heteroscedasticity and found the presence of heteroscedasticity in the firm's performance measurement. We also checked for autocorrelation; we ran the different measures, and since the coefficients are not close to 1 and there is no autocorrelation, we performed a remedial test for heteroscedasticity. The Breusch-Pagan Lagrange multiplier test was used to determine cross-sectional dependence, but our test results show no cross-sectional dependence.

Insert Table 2 about here.

5.1 Main Effect:

To choose the best model, we ran several tests. Since our model has heteroscedasticity, we used a feasible generalized least squares model. Furthermore, the Hausman test (Greene, 2003) demonstrated that the performance of the random-effects panel data model was superior to that of the fixed-effects panel data model. We chose a random effects panel data model to determine the effects of OI practice on the Board of Directors external renewal, their expertise and experience in technology and innovation orientation, and the interlock and collaborations on firm performance. To test the hypotheses, we utilized Stata to apply the random and fixed effect-GLS estimator to the following model.

The main models represent firm performance measures and are given below:

$$\text{Tobin } Q_{it} = a_0 + a_1 * \text{OI practice}_{i(t-1)} + a_2 * (\text{NBR}_{i(t-1)} + \text{BHC}_{i(t-1)} + \text{BSC}_{i(t-1)}) + a_3 * X_{i(t-1)} + u_i + e_{it} \dots (1)$$

$$\text{ROS}_{it} = a_0 + a_1 * \text{OI practice}_{i(t-1)} + a_2 * (\text{NBR}_{i(t-1)} + \text{BHC}_{i(t-1)} + \text{BSC}_{i(t-1)}) + a_3 * X_{i(t-1)} + u_i + e_{it} \dots (2)$$

For robustness check, the other two models are included and are given below:

$$\text{ROA}_{it} = a_0 + a_1 * \text{OI practice}_{i(t-1)} + a_2 * (\text{NBR}_{i(t-1)} + \text{BHC}_{i(t-1)} + \text{BSC}_{i(t-1)}) + a_3 * X_{i(t-1)} + u_i + e_{it} \dots (3)$$

$$\text{ROE}_{it} = a_0 + a_1 * \text{OI practice}_{i(t-1)} + a_2 * (\text{NBR}_{i(t-1)} + \text{BHC}_{i(t-1)} + \text{BSC}_{i(t-1)}) + a_3 * X_{i(t-1)} + u_i + e_{it} \dots (4)$$

Where “OI practice” includes (Partial tech M&A and alliances). The control variables $X_{i(t-1)}$ include firm size, firm age, investment in human capital, leverage, R&D intensity, board size, board meeting frequency, and board compensation.

Feasible GLS results and the primary model estimation with random and fixed effects GLS regression results are shown in the table where * represents $p < 0.01$, ** represents $p < 0.05$, *** represents $p < 0.1$.

Insert Table 3 & 4 about here.

5.2 Mediation effect:

$$FP_{it} = a_0 + a_1*(NBR_{i(t-1)} + BHC_{i(t-1)} + BSC_{i(t-1)}) + u_i + e_{it} \dots\dots\dots (5)$$

$$OI\ practice_{it} = a_0 + a_2*(NBR_{i(t-1)} + BHC_{i(t-1)} + BSC_{i(t-1)}) + u_i + e_{it} \dots\dots\dots (6)$$

$$FP_{it} = a_0 + a_4*(NBR_{i(t-1)} + BHC_{i(t-1)} + BSC_{i(t-1)}) + a_3*OI\ practice_{i(t-1)} + u_i + e_{it} \dots\dots\dots (7)$$

According to Barron and Kenny (1986), for a mediation effect to occur, coefficients a1, a2, and a3 must be significant, and a4 should be smaller than a1. Our test results show that for our primary model 1 (Tobin Q) and model 2 (ROS) – a1, a2, and a3 are significant, and a4 is smaller than a1. Thus, a partial mediation exists (See table 5a & 5b).

Insert Table 5a about here

Insert Table 5b about here

5.3 Robustness tests:

Insert Table 6 about here

For robustness checks (Table 6), we used mediating effects: Sobel test (Boh et al., 2020) using the formula $z\text{-value} = a_2*a_3/\text{SQRT}(a_3^2*s_2^2 + a_2^2*s_3^2)$. The percentage of indirect to direct effects is given in the figure. The Sobel test determines an indirect effect between new board renewal, board human capital, board social capital, and the firm performance variable mediated by OI practice. Mediation is observed when four conditions are met: (1) the independent variable (IV) has a significant impact on the mediator, (2) the IV has a significant impact on the dependent variable (DV) even without the mediator, (3) the mediator has a significant and distinct impact on the DV, and (4) the effect of the IV on the DV diminishes when the mediator is included in the model.

Our study shows that board antecedents promote OI practice, but this may have endogeneity issues. This research tests endogeneity using the Durbin-Wu-Hausman test using instrument variables and

found that the null hypothesis is rejected ($p\text{-value} = 0.02$). This means that the endogeneity issue is a potential concern for our analysis. To address the potential endogeneity concerns, this paper uses the type of industry (1 indicated manufacturing industry, otherwise 0), available slack with 2 years of lag measured as the ratio of net income to sales, added patents in that year with a 1-year lag, as instrumental variables using two-stage least squares (2SLS) (Chen, 2014). Over-identification and weak instrumental variable tests are conducted before the regression with panel instrumental variables. Model 1 – Tobin Q measure shows that instrument variable Industry type gives significant results for Board experience and knowledge (Coeff. = 0.116, $p\text{-value} = 0.000$). Model 2 – ROA measure shows using instrument variable Available slack with 2 years of lag gives significant results for Board renewal (Coeff. = -0.064, $p\text{-value} = 0.012$), Board experience and knowledge (Coeff. = -0.02, $p\text{-value} = 0.018$) and instrument variable patent added with lag 1 gives significant results for board human capital (Coeff. = 0.085, $p\text{-value} = 0.018$). Model 3 – ROE measure shows using instrument variable Available slack with 2 years of lag gives significant results for Board renewal (Coeff. = -0.11, $p\text{-value} = 0.008$), Board human capital (Coeff. = -0.036, $p\text{-value} = 0.015$) and instrument variable patent added with lag 1 gives significant results for board experience and knowledge (Coeff. = -0.049, $p\text{-value} = 0.000$). Model 4 – ROS measure shows using instrument variable patent added with lag 1 gives significant results for Board human capital (Coeff. = 0.059, $p\text{-value} = 0.037$).

6. DISCUSSION

6.1 Theoretical Implications

The results of our empirical study strongly align with our hypotheses. We made theoretical advances in OI research by fusing capital theory (Human and social) with the context of the board. Board capital is important in increasing OI practice in organizations. We can understand how the

upper echelons, like board members, can bring knowledge, expertise, and skills through their connections and experience (Tsinopoulos & Yan, 2018). This study also contributes to board capital theory by linking it to Open innovation practices, which mediates the relationship between board capital (Human and social) and the renewal of board members with firm performance.

The upper echelons, such as the board members, must be renewed to enhance OI practice in an organization. Having board members with more experience and interlocked people can bring better diversity with more knowledge and experience, enhancing the capability to establish partnerships and develop new products or services at a lower level. Combining these viewpoints could provide crucial insights into the connection between board interlock and business performance. To do this, we emphasize the level of resources at the focal and other firms that make up the interlocks as a crucial mechanism that connects the two theories' predictions and aids in resolving the results currently found in the board interlock literature that appear to be at variance. Because adopting interlocks as a practice to deal with external dependencies may depend on the resources available, the conclusions about the relationship between board interlocks and business performance may be inconsistent. In this research, we examine the relationship between social capital and board composition and formulate hypotheses regarding how each affects the relationship between social capital and director selection and, ultimately, the efficacy of the board.

Partner firms' capabilities vary significantly in a considerable number of collaborations. Companies engage in interfirm collaboration to access other companies' capabilities, enabling a more concentrated and thorough utilization of the existing capabilities inside each company (Mowery et al., 1996). Thus, the mediating effect of OI practice, such as partial M&A (technology-based), licensing, collaborating through a joint venture, or any other technology transfer to tap resources like knowledge, skills, and technology, helps the organization improve firm

performance. Board capital can be utilized to improve the OI practice of an organization; it not only improves the practical knowledge and ideas outsourcing but also improves a company's financial performance. By highlighting the importance of corporate leaders' values and resources in influencing OI practice and firm performance, this work expands the corpus of theoretical knowledge by extending OI literature from the point of view of the board member's characteristics.

6.2 Managerial practices of OI

This study addresses that external sources of innovation can enter the firm through various OI practices and recommends that the upper echelons or executives involved in OI practice collaborate strongly with stakeholders from whom an inflow of ideas or knowledge can be generated and can sense and implement better OI practices. Secondly, if the board is renewed with external members recruited from outside the organization, they will help bring more external ideas, knowledge and resources to the organization. It is also advisable to have an optimal tenure of board members, which should not decrease the board's OI-related functioning. Third, activities like joint ventures, alliances, agreements, licensing, and partial M&A are important for obtaining external ideas and knowledge for the firm. Thus, practitioners need to follow all the practices suitable for their firm.

7. CONCLUSION AND FUTURE SCOPE

The aggregate impact of OI practice on strengthening the link between board antecedents and financial performance was challenging to measure empirically due to many influences on the outcomes (Kor, 2006). Our study builds on the earlier studies (Jeremias & Gani, 2014; Shen, 2019; Wincent et al., 2013) by offering a more in-depth analysis of how the partial mediating effect of OI practices like alliances, joint ventures, and partial technology M&A impacts the relation between board capital and firm performance. Using board human and social capital theory, the

novelty of the current study shows that the board of directors' capabilities and knowledge in technology and innovation help absorb and utilize resources in organizations better. Firstly, we explained how the board of directors affects a company's dependency on outside resources, particularly those related to R&D, technology and innovation. Additionally, we contribute significantly to understanding how board capabilities emerge at the individual level and take the first step towards bridging the gap between the theory of the upper echelon and the idea of resource dependency theory. This study addresses several research limitations from earlier studies that have not considered the board capital antecedents. One of the limitations and scope of future research is that our study considers only the renewal of board members; future researchers can look for renewing—board members with various director diversity and other dimensions of the board. Further studies can be done considering SMEs as one of the study contexts. Further scope of the study can be identified by identifying the potential hiring of new members in the organization at various hierarchies.

APPENDIX

Insert Table 7 about here.

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Table 1
Descriptive analysis

Variable	Obs.	Mean	Std. dev.	Min	Max
Tobin Q	2,813	- 0.2145	0.8329	- 1.9929	1.9960
Return On Assets	2,854	0.0889	0.1469	- 1.8198	1.0083
Return On Equity	2,859	0.1920	0.2481	- 1.9535	1.8750
Return On Sales	2,841	0.1062	0.3644	- 2.0000	1.9769
Open Innovation	2,859	0.5547	2.4696	0	36
New Board Renewal	1,576	1.0698	1.3386	0	10

Board Human Capital	1,576	8.4956	5.2401	0	33
Board Social Capital	2,149	21.0721	20.4413	0	151
Firm Size	2,853	3.6584	0.8457	0.0414	9.0791
Firm Age	2,859	30.7079	14.8621	0	98
Investment in human capital	2,840	2.8085	0.9187	-1.0000	5.6688
Leverage	2,627	0.2196	0.2781	0.000	3.9785
R&D Intensity	1,506	0.0204	0.0346	0.000	0.3185
Board Size	2,859	8.1735	4.3301	1	15
Board Meeting Frequency	2,247	0.9572	0.7641	0	12
Board Compensation	2,178	1.3836	0.7155	-1.9208	3.4728

Note: Abbreviation: ROA = Return on Assets, ROE = Return on Equity, ROS = Return on sales, R&D = Research and development. Please note that all the information is obtained from different sources, as mentioned in the methodology section.

Table 2
Pairwise Correlation Matrix

	Tobin Q	Return On Assets	Return On Equity	Return On Sales	Open innovation Practices (t-1)	New Board Renewal (t-2)	Board Human Capital (t-2)	Board Social Capital (t-2)	Firm Size (t-1)	Firm Age (t-1)	Investment in Human Capital (t-1)	Leverage (t-1)	R&D Intensity (t-1)	Board Size (t-1)	Board Meeting (t-1)	Board Compensation (t-1)
Tobin Q	1															
Return On Assets	0.0636* (0.0007)	1														
Return On Equity	0.0381** (0.0432)	0.4108* (0.000)	1													
Return On Sales	0.0364*** (0.0537)	0.3958* (0.000)	0.2260* (0.000)	1												

Open Innovation Practices (t-1)	0.107 9*	0.09 87*	0.06 32* (0.0 019)	0.04 97** (0.0 147)	1																
	(0.00 00)	(0.0 000)																			
New Board Renewal (t-2)	- 0.020 3	0.07 14**	- 0.01 06 (0.7 199)	0.02 38 (0.4 206)	0.01 72 (0.5 621)	1															
	(0.49 17)	(0.0 154)																			
Board Human Capital (t-2)	- 0.048 8 ***	0.14 69*	0.02 78 (0.3 470)	0.07 95* (0.0 070)	0.32 15* (0.0 000)	0.30 07* (0.0 000)	1														
	(0.09 84)	(0.0 000)																			
Board Social Capital (t-2)	0.066 9*	0.09 23*	0.13 64* (0.0 000)	0.00 8 (0.7 502)	0.13 30* (0.0 000)	0.11 84* (0.0 001)	0.28 16* (0.0 000)	1													
	(0.00 79)	(0.0 002)																			
Firm Size (t-1)	0.123 3*	0.15 55*	0.12 91* (0.0 000)	0.09 43* (0.0 000)	0.33 77* (0.0 000)	0.09 30* (0.0 017)	0.33 33* (0.0 000)	0.410 5* (0.00 00)	1												
	(0.00 00)	(0.0 000)																			
Firm Age (t-1)	0.035 7***	0.05 74*	0.07 62* (0.0 002)	0.07 04* (0.0 006)	0.13 55* (0.0 000)	0.01 46 (0.6 232)	0.12 43* (0.0 000)	0.148 2* (0.00 00)	0.27 65* (0.0 000)	1											
	(0.08 13)	(0.0 047)																			
Invest.i n Human Capital (t-1)	0.112 4*	0.23 34*	0.17 10* (0.0 000)	0.10 53* (0.0 000)	0.25 84* (0.0 000)	0.09 14* (0.0 020)	0.41 64* (0.0 000)	0.360 7* (0.00 00)	0.78 45* (0.0 000)	0.16 46* (0.0 000)	1										
	(0.00 00)	(0.0 000)																			
Levera ge (t-1)	0.075 7*	0.25 21*	0.03 13 (0.1 409)	0.19 10* (0.0 000)	0.11 72* (0.0 000)	0.01 48 (0.6 274)	0.18 69* (0.0 000)	0.046 8*** (0.07 37)	0.08 43* (0.0 001)	0.02 61 (0.2 195)	0.20 89* (0.0 000)	1									
	(0.00 04)	(0.0 000)																			
R&D Intensit y (t-1)	- 0.026 6	- 0.03 88	0.09 32* (0.0 007)	0.03 69 (0.1 829)	0.01 34 (0.6 290)	0.00 65 (0.8 521)	0.04 37 (0.2 124)	0.105 3* (0.00 08)	0.20 62* (0.0 000)	0.05 65** (0.0 411)	0.12 83* (0.0 000)	0.00 4 (0.8 871)	1								
	(0.33 78)	(0.1 608)																			
Board Size (t-1)	0.065 4*	0.12 01*	0.10 27* (0.0 000)	0.11 69* (0.0 000)	0.01 57 (0.4 396)	0.04 69 (0.1 134)	0.19 09* (0.0 000)	0.299 7* (0.00 00)	0.34 43* (0.0 000)	0.36 36* (0.0 000)	0.33 73* (0.0 000)	0.09 53* (0.0 000)	0.08 82* (0.0 014)	1							
	(0.00 14)	(0.0 000)																			
Board Meetin g (t-1)	0.008 7	- 0.06 57*	0.00 94 (0.6 798)	- 0.05 50** (0.0 161)	- 0.03 48 (0.1 273)	0.05 09 (0.1 122)	0.04 9 (0.1 261)	- 1*** (0.06 33)	0.15 22* (0.0 000)	- 58 (0.7 992)	0.17 17* (0.0 000)	0.03 43 (0.1 496)	- 42 (0.4 180)	0.02 85 (0.2 114)	1						
	(0.70 62)	(0.0 040)																			
Board Compe nsation (t-1)	0.074 0*	0.28 69*	0.18 31* (0.0 000)	0.12 90* (0.0 000)	0.28 49* (0.0 000)	0.04 63 (0.1 513)	0.30 84* (0.0 000)	0.412 2* (0.00 00)	0.72 57* (0.0 000)	0.27 50* (0.0 000)	0.67 55* (0.0 000)	0.21 64* (0.0 000)	0.20 94* (0.0 000)	0.37 22* (0.0 000)	0.16 71* (0.0 000)	1					
	(0.00 14)	(0.0 000)																			

	000)	000)	000)	000)	000)	000)
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Note: Here *means (p-value < 0.01), ** means (p-value <0.05), *** means (p-value <0.1), Mediator variable = Open innovation (OI) Practice and control variables like firm size, firm age, investment in human capital, leverage, R&D Intensity, Board size, Board meeting and Board compensation are being 1 year lagged. Independent variables like Board Renewal, Board human and social capital lagged by 2 years, with the dependent variable FP = Firm performance (measured in terms of Tobin Q, ROA, ROS & ROE).

Table 3
Primary model Tobin Q and ROS regression results

Model Variables	Tobin Q			ROS		
	F-GLS	RE	FE	F-GLS	RE	FE
Open Innovation Practice (t-1)	-0.0023 (0.810)	-0.0023 (0.829)	-0.0023 (0.829)	-0.0014 (0.795)	-0.0014 (0.815)	-0.0014 (0.815)
New Board Renewal (t-2)	.0461* (0.010)	.0461** (0.020)	.0461** (0.020)	0.0248** (0.020)	0.0248** (0.036)	0.0248** (0.036)
Board Human Capital (t-2)	-.0178 (0.202)	-.0178 (0.252)	-0.0178 (0.252)	- 0.0231* (0.006)	- 0.0231** (0.013)	- 0.0231** (0.013)
Board Social Capital (t-2)	.0038** (0.045)	.0038*** (0.072)	.0038*** (0.072)	0.0005 (0.679)	0.0005 (0.710)	0.0005 (0.710)
Firm Size (t-1)	.2647 (0.215)	.2647 (0.265)	0.2647 (0.265)	-0.0371 (0.771)	-0.0371 (0.793)	-0.0371 (0.793)
Firm Age (t-1)	.0101 (0.571)	.0101 (0.610)	0.0101 (0.611)	0.0146 (0.166)	0.0146 (0.213)	0.0146 (0.213)
Investment in human capital (t-1)	-.1330 (0.442)	-.1330 (0.490)	-0.1330 (0.490)	-0.1 (0.332)	-0.1 (0.384)	-0.1 (0.384)

Leverage (t-1)	.4675 (0.104)	.4675 (0.144)	0.4675 (0.145)	-0.1735 (0.310)	-0.1735 (0.362)	-0.1735 (0.362)
R&D Intensity (t-1)	-.0233 (0.987)	-.0233 (0.988)	-0.0233 (0.988)	-1.1637 (0.176)	-1.1637 (0.224)	-1.1637 (0.224)
Board Size (t-1)	-.0144*** (0.087)	-.0144 (0.124)	-0.0144 (0.125)	0.0015 (0.765)	0.0015 (0.788)	0.0015 (0.788)
Board Meeting Frequency (t-1)	.0465 (0.132)	.0465 (0.175)	0.0465 (0.176)	0.0067 (0.715)	0.0067 (0.743)	0.0067 (0.743)
Board Compensation (t-1)	.003 (0.972)	.003 (0.975)	0.003 (0.975)	-0.0169 (0.742)	-0.0169 (0.767)	-0.0169 (0.767)
Industry effect	Yes	yes	yes	Yes	yes	yes
Year effect	Yes	yes	yes	Yes	yes	yes
Prob>chi2 or F statistics	0	0	0.0555	0	0	0.335
Hausman p-value		0	fixed effect		0	fixed effect

Note: Dependent variables (DV) for model 1 is Tobin Q and model 2 is ROS. All models include year and industry dummies. *Means (p-value < 0.01), ** means (p-value <0.05), *** means (p-value <0.1).

Table 4
Robustness Models for ROA and ROE Results

Model Variables	ROA			ROE		
	F-GLS	RE	FE	F-GLS	RE	FE
Open Innovation Practice (t-1)	0.0007 (0.692)	0.0007 (0.722)	0.0007 (0.722)	0.0021 (0.444)	0.0021 (0.491)	0.0021 (0.492)
New Board Renewal (t-2)	0.0083** (0.011)	0.0083** (0.022)	0.0083** (0.022)	0.0044 (0.387)	0.0044 (0.436)	0.0044 (0.437)
Board Human Capital (t-2)	-0.0031 (0.218)	-0.0031 (0.268)	-0.0031 (0.268)	-0.001 (0.810)	-0.001 (0.829)	-0.001 (0.829)

Board Social Capital (t-2)	0.0006 (0.114)	0.0006 (0.156)	0.0006 (0.156)	0.0002 (0.782)	0.0002 (0.804)	0.0002 (0.804)
Firm Size (t-1)	- 0.1819* (0.000)	- 0.1819* (0.000)	- 0.1819* (0.000)	- 0.2576* (0.000)	- 0.2576* (0.000)	- 0.2576* (0.000)
Firm Age (t-1)	0.0073** (0.023)	0.0073** (0.041)	0.0073** (0.041)	0.0013 (0.801)	0.0013 (0.820)	0.0013 (0.820)
Investment in human capital (t-1)	0.0169 (0.592)	0.0169 (0.630)	0.0169 (0.630)	0.0343 (0.491)	0.0343 (0.535)	0.0343 (0.535)
Leverage (t-1)	0.0033 (0.950)	0.0033 (0.955)	0.0033 (0.955)	0.2620* (0.001)	0.2620* (0.004)	0.2620* (0.004)
R&D Intensity (t-1)	-0.1641 (0.532)	-0.1641 (0.575)	-0.1641 (0.575)	- 0.9944** (0.017)	- 0.9944** (0.031)	- 0.9944** (0.032)
Board Size (t-1)	0.001 (0.487)	0.001 (0.532)	0.001 (0.532)	0.0023 (0.348)	0.0023 (0.398)	0.0023 (0.399)
Board Meeting Frequency (t-1)	0.0012 (0.830)	0.0012 (0.847)	0.0012 (0.847)	-0.003 (0.739)	-0.003 (0.764)	-0.003 (0.764)
Board Compensation(t-1)	0.0239 (0.126)	0.0239 (0.169)	0.0239 (0.169)	0.0305 (0.216)	0.0305 (0.266)	0.0305 (0.267)
Industry effect	Yes	yes	yes	Yes	yes	yes
Year effect	Yes	yes	yes	Yes	yes	yes
Prob>chi2 or F statistics	0	0	0.0002	0	0	0.0001
Hausman p-value		0	fixed effect		0	fixed effect

Note: The dependent variables (DV) for model 3 is ROA and model 4 is ROE. All models include year and industry dummies. *Means (p-value < 0.01), ** means (p-value <0.05), *** means (p-value <0.1).

Table 5a
Main mediation model 1(Tobin Q) and Model 2 (ROS)

	Model 1	Model 2
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	Tobin Q	OI Practice	Tobin Q	ROS	OI Practice	ROS
	Eq5	Eq6	Eq7	Eq5	Eq6	Eq7
Open Innovation Practice (t-1)			-.0023 (0.810)			-0.0014 (0.795)
New Board Renewal (t-2)	.0463* (0.009)	-.1187 (0.103)	.0461* (0.010)	0.0249* * (0.019)	-.1187 (0.103)	0.0248* * (0.020)
Board Human Capital (t-2)	-.0182 (0.188)	.1964* (0.001)	-.0178 (0.202)	- 0.0234* (0.005)	.1964* (0.001)	- 0.0231* (0.006)
Board Social Capital (t-2)	.0038* * (0.045)	.0023 (0.767)	.0038** (0.045)	0.0005 (0.681)	.0023 (0.767)	0.0005 (0.679)
Firm Size(t-1)	.2598 (0.221)	2.193 (0.012)	.2647 (0.215)	-0.0402 (0.751)	2.193 (0.012)	-0.0371 (0.771)
Firm Age(t-1)	.0095 (0.589)	.2445* (0.001)	.0101 (0.571)	0.01424 (0.173)	.2445* (0.001)	0.0146 (0.166)
Investment in human capital(t-1)	-.1239 (0.463)	-4.0512* (0.000)	-.1330 (0.442)	-0.0941 (0.350)	- 4.0512* (0.000)	-0.1 (0.332)
Leverage(t-1)	.4615 (0.107)	2.6635** (0.023)	.4675 (0.104)	-0.1773 (0.298)	2.6635* * (0.023)	-0.1735 (0.310)
R&D Intensity(t-1)	-.0065 (0.996)	-7.4779 (0.205)	-.0233 (0.987)	-1.1529 (0.180)	-7.4779 (0.205)	-1.1637 (0.176)
Board Size(t-1)	- .014** * (0.090)	-.1749* (0.000)	- .0144** * (0.087)	0.0017 (0.721)	-.1749* (0.000)	0.0015 (0.765)
Board Meeting Frequency(t-1)	.0459 (0.136)	.2780** (0.027)	.0465 (0.132)	0.0063 (0.730)	.2780** (0.027)	0.0067 (0.715)
Board Compensation(t-1)	.0040 (0.962)	-.4775 (0.174)	.0029 (0.972)	-0.0162 (0.752)	-.4775 (0.174)	-0.0169 (0.742)

Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
Prob>chi2	0	0	0	0	0	0

Table 5b
Main mediation model 3(ROA) and Model 4 (ROE)

	Model 3			Model 4		
	ROA Eq5	OI Practice Eq6	ROA Eq7	ROE Eq5	OI Practice Eq6	ROE Eq7
Open Innovation Practice (t-1)			0.0007 (0.692)			0.0021 (0.444)
New Board Renewal (t-2)	0.0082* * (0.011)	-.1187 (0.103)	0.0083* * (0.011)	0.0042 (0.413)	-.1187 (0.103)	0.0044 (0.387)
Board Human Capital (t-2)	-0.003 (0.234)	.1964* (0.001)	-0.0031 (0.218)	- 0.0006 (0.888)	.1964* (0.001)	-0.001 (0.810)
Board Social Capital (t-2)	0.0006 (0.113)	.0023 (0.767)	0.0006 (0.114)	0.0002 (0.776)	.0023 (0.767)	0.0002 (0.782)
Firm Size(t-1)	- 0.1805* (0.000)	2.193 (0.012)	- 0.1819* (0.000)	- 0.2531* (0.000)	2.193 (0.012)	- 0.2576* (0.000)
Firm Age(t-1)	0.0075* * (0.019)	.2445* (0.001)	0.0073* * (0.023)	0.0018 (0.723)	.2445* (0.001)	0.0013 (0.801)
Investment in human capital (t-1)	0.0141 (0.646)	-4.0512* (0.000)	0.0169 (0.592)	0.0260 (0.593)	-4.0512* (0.000)	0.0343 (0.491)
Leverage(t-1)	0.0051 (0.922)	2.6635** (0.023)	0.0033 (0.950)	0.2675* (0.001)	2.6635** (0.023)	0.2620* (0.001)
R&D Intensity(t-1)	-0.1692 (0.519)	-7.4779 (0.205)	-0.1641 (0.532)	1.010** (0.015)	-7.4779 (0.205)	- 0.9944* * (0.017)

Board Size(t-1)	0.0009 (0.529)	-.1749* (0.000)	0.001 (0.487)	0.0019 (0.421)	-.1749* (0.000)	0.0023 (0.348)
Board Meeting Frequency(t-1)	0.0014 (0.804)	.2780** (0.027)	0.0012 (0.830)	- 0.0024 (0.787)	.2780** (0.027)	-0.003 (0.739)
Board Compensation(t-1)	0.024 (0.131)	-.4775 (0.174)	0.0239 (0.126)	0.030 (0.231)	-.4775 (0.174)	0.0305 (0.216)
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
Prob>chi2	0	0	0	0	0	0

Note: *Means (p-value < 0.01), ** means (p-value <0.05), *** means (p-value <0.1)

Table 6
Direct and indirect effect (Sobel Test)

Independent variable	Dependent Variable	Direct effect			Indirect effect	Total Effect	The ratio of indirect effect to total effect
		Coeff.	Std. error	p-value	Coeff.	Coeff.	
New Board Renewal	Tobin Q	0.037**	0.017	0.031	-0.319	-0.282	113.00%
	ROS	0.015	0.01	0.121	0.578	0.593	97.40%
	ROA	0.007**	0.003	0.016	-0.075	-0.067	110.90%
	ROE	0.004	0.005	0.452	-0.437	-0.434	100.80%
	OI	-0.017	0.024	0.472	-	-	-
Board Human Capital	Tobin Q	-0.006	0.013	0.63	0.291	0.284	102.30%
	ROS	-0.017**	0.008	0.032	-0.447	-0.464	96.40%
	ROA	-0.0004	0.002	0.854	0.074	0.0738	100.50%
	ROE	0.001	0.004	0.871	0.372	0.372	99.80%
	OI	0.009	0.018	0.639	-	-	-
Board Social Capital	Tobin Q	0.002	0.002	0.183	0.347	0.35	99.30%
	ROS	0.0002	0.001	0.831	-0.832	- 0.8319	100.00%
	ROA	0.0004	0.0003	0.117	0.075	0.0753	99.40%
	ROE	0.001	0.001	0.324	0.521	0.521	99.90%
	OI	0.003***	0.002	0.082	-	-	-

Open Innovation practice	Tobin Q	0.01	0.028	0.722	-	-	-
	ROS	-0.013	0.013	0.338	-	-	-
	ROA	0.0003	0.004	0.935	-	-	-
	ROE	0.005	0.009	0.596	-	-	-

Note: Sobel test results represent board antecedents' direct and indirect effects on firm performance measures. * (p-value < 0.01), ** (p-value <0.05), *** (p-value <0.1).