How Board of Directors' Social Capital Enhances the Effectiveness of IT and R&D Resources Toward More Effective Innovation

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Abstract

A board of directors (BOD) plays a critical governance and strategic oversight role in an organization; acting as a fiduciary for shareholders, advising strategic decision making, and providing supportive resources and information to key decision makers. Especially critical is the role and contribution of corporate governance in guiding firm innovation. Such guidance has implications for investment in new products and services. In this paper, we examine the synergistic relationship between a firm's BOD and technology and R&D inputs to innovation. We focus on the influence of the social capital of a BOD on different types of innovation. Our longitudinal findings show IT, R&D, and BOD social capital individually contribute to innovation performance, reflected in exploitative and exploratory innovation productivity. Moreover, BOD social capital enhances innovation enabled by IT activities. However, the combination of R&D activities and dimensions of BOD social capital leads to both negative and positive innovation performance.

Keywords: Board of directors (BOD), business value of IT (BVIT), information technology (IT), innovation, social capital

1. Introduction

Innovation is a driving force in today's economy and plays a key role in the competitive success of an organization (Joshi et al., 2010; Kleis et al., 2012). Globalization and rapid technological changes are forcing firms to pay more attention to innovation in order to grow and survive in an increasingly dynamic environment (Prasad & Junni, 2016). Investing in new technologies, products or services is a complex decision and often leads to organizational commitments that change business processes (Ravichandran et al., 2017). This can be risky as change brings new forms of uncertainty, leading to the involvement of top management in decision making for critical processes. Research highlights the involvement and critical value of top management in a firm's knowledge creation and innovation (Custódio et al., 2019). A firm's CEO, for instance, can facilitate innovation through the acquisition of knowledge and skills beyond the firm's current technological domain (Custódio et al., 2019). A CEO's transformational and transactional leadership capabilities can also spur organizational innovation by motivating and empowering employees to be creative and innovative (Prasad & Junni, 2016).

There have been situations, however, when decision making has led to a loss of competitiveness. Between 2001 and 2004, for instance, Mattel lost 20% of its market share in the fashion-doll industry to smaller competitors such as MGA Entertainment (Day & Schoemaker, 2005). A central reason was Mattel's failure to keep its Barbie doll product in tune with the subtle shifts in the pre-teen market. Although the chocolate industry generates over $75 billion in sales annually, many businesses such as Nestlé and Hershey are struggling with market leadership given constant shifts in consumer behavior, expectation, and shopping patterns (Day & Schoemaker, 2019).

Long term inconsistent performance by companies like Mattel and chocolate confectioners highlights the importance of market sensemaking, information acquisition, and appropriate information analysis. There is also the challenge of the scale of data generated today. Firms are now prone to information overload and confusion, as noise in the incoming flow of data may be emphasized rather than relevant signals. While more data provides diverse information

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and new insight opportunity, the bounded rationality of managers and executives limits what can be harnessed. This challenge hinders the ability of innovators to separate noise from facts and actionable insights (Eisenhardt & Zbaracki, 1992). A firm's long term competitiveness and survivability will be threatened unless this challenge can be overcome (Day & Schoemaker, 2019). To remain relevant, firms must acquire a capability to effectively identify relevant signals from their environment to strategically improve their competitive position, develop new market opportunities, and pursue performance improvement (Schoemaker, 2008). Proctor & Gamble, for example, enhanced its capability to respond to weak signals early in the digital era, enabling a critical shift in its marketing processes and movement of its advertising spend to new digital channels. The result was e-commerce sales of $3 billion in 2017, outperforming its closest rivals (Venkatraman, 2019).

A mechanism that enables a firm to sense new market changes and opportunities is its board of directors (BOD). A BOD is a governance mechanism that helps a corporation solve agency problems and guarantees the interests of its principal owners (Kim, 2005). In addition, a BOD helps a firm to perceive and interpret signals in market information. Essential to this is the BOD's ability to filter out noise and identify key information and opportunity from the river of data flowing in the marketplace. This insight enables a firm's executives to take quick action to build market advantage (Johnson et al., 2013; Lee et al., 2012), through new innovation in products and services (Chang & Wu, 2021; Wincent et al., 2010).

In this study, we focus on a BOD's social capital as a key externality that contributes to higher levels of firm performance through innovation (Barroso-Castro et al., 2016; Wincent et al., 2010). A BOD's social capital can be defined as the degree to which a BOD has external connections within an institutional environment (Kim, 2005). Literature highlights the role of top management's and BOD's social capital for an innovation impact. Faleye et al. (2014), for example, show that CEO connections provide alternative perspectives that improve the quality of strategic choices in new settings like those involved in the development of new products or services. Also, these connections enable a CEO to access unique information that improves their ability to identify and exploit innovation opportunities. Chang & Wu (2021) show that firms with well-connected boards generate better performance in innovation activities. Well-connected boards can reduce information asymmetry in the firm and improve the diffusion of information. For example, a BOD can improve the exchange of information between a firm and banks to reduce the cost of debt and access larger loans.

IT and R&D resources are essential to a firm's knowledge creation and innovation. The adoption of technologies like ERP systems (Joshi et al., 2010) and data analytics (Wu et al., 2020) has enabled informed-insights for business process improvement and new product development. Technologies allow a firm to integrate, disseminate, and utilize external knowledge within critical processes (Joshi et al., 2010). IT can contribute to speed and efficiency improvements, such as in a firm's innovation process (Kleis et al., 2012). Similarly, research and development (R&D) plays a critical role in innovation performance. R&D involves a set of activities that utilize a firm's technological capabilities and knowledge assets to develop novel concepts reflected in new products, processes, and services (Kleis et al., 2012). R&D leads to market opportunities through the discovery, design, and creation of new methods, products, and services (Hall et al., 2013).

Existing research outlines how investments in R&D and IT contribute to the innovation output of firms, focusing on the results of the post-investment decision of how much to invest in each input. To our knowledge, no research has examined how a governing body, such as a BOD upon its function and strategic guidance, influences the productivity of a firm's innovation enabled by key organizational resources. The quantity or frequency of innovation can demonstrate a firm's innovation productivity and has been extensively examined in innovation performance research (Chang & Wu, 2021; Custódio et al., 2019).

Therefore, there is a need to closely investigate if a BOD enhances the use of key organizational resources like those related to IT and R&D for more effective knowledge creation and innovation. This is important as a BOD can provide relevant and insightful information to guide a firm's strategic decision making process related to innovation. This role is critical in the digital era given the scale of information, which can lead to overwhelming amounts of data that may contain irrelevant information (Day & Schoemaker, 2019). As such, a firm's executives may rely on suboptimal or misleading information for innovation decision making. A BOD helps reduce this risk by providing essential knowledge and capability for interpreting information and identifying key insights (Hendry & Kiel, 2004). In addition, a BOD can help a firm to redirect information flow and to help aggregate information flows that, by themselves, might not yield any insights. Moreover, a BOD can inform a firm's executives and provide strategic directions that help for an agile adaptation to an environmental change (Johnson et al., 2013). If a

firm's BOD is of strategic value, such guidance should lead to the creation of new innovations that produce new sources of revenues, profits, and market advantage (Hall et al., 2013).

In sum, we argue BOD social capital, through improving organizational decision making, can enhance the effectiveness of a firm's capabilities enabled by technological and R&D resources, and these combinations can lead to improved knowledge creation and innovation in the firm. Therefore in this study, we examine the following research question: How does BOD, through its social capital, guide IT and R&D resources toward more effective innovation? To examine this question, we first turn to the theory of social capital (Coleman, 1994) and business value of IT (BVIT) for knowledge creation and innovation (Joshi et al., 2010; Kleis et al., 2012; Ravichandran et al., 2017) to develop a framework for the synergistic benefits of IT, R&D, and BOD social capital.

We examine the productivity of a firm's innovation activities using patent-based metrics. We use the United States Patent and Trademark Office database (USPTO) to measure the quantity of a firm's innovation output (Custódio et al., 2019). We measure innovative activity by the annual number of patents that each firm files. We test our theoretical framework through an empirical analysis of a longitudinal dataset of 1,982 publicly traded US firms. Random effects (RE) estimation results broadly provide support for our hypotheses, indicating that IT, R&D, and BOD social capital individually contribute to a firm's knowledge creation performance as reflected in exploratory and exploitative innovation productivity. Moreover, BOD social capital complements IT as a key organizational resource for an impact on exploratory and exploitative innovation performance. However, the combination of R&D activities with dimensions of BOD social capital leads to both negative and positive innovation performance. The negative combination may speak to the inefficiency of R&D activities when they scale (Ravichandran et al., 2017).

Our study broadly shows BOD social capital is a critical complement to technological capabilities and extends research on the role of IT and R&D resources (Hall et al., 2013; Joshi et al., 2010; Kleis et al., 2012; Ravichandran et al., 2017) and BOD (Balsmeier et al., 2017; Chang & Wu, 2021; Chuluun et al., 2017; Sierra-Morán et al., 2021) in organizational innovation performance such as the quality, quantity, and speed of innovation. Therefore, our study provides a new perspective for developing corporate level strategies.

2. Literature and background

Research on innovation performance distinguishes between the creation of new knowledge (exploratory) and the use of existing knowledge (exploitative), and highlights organizational processes that support unique types of technology-enabled innovations (Chang & Wu, 2021; Custódio et al., 2019; Wu et al., 2020). Based on this literature, we conceptualize innovation as involving the integration of a firm's existing knowledge with new knowledge or the integration of a firm's existing knowledge in novel ways (Jansen et al., 2006). Exploratory innovations, as radical knowledge, are developed to target a new market or a customer segment. On the other hand, exploitative innovations, as incremental knowledge, are developed for the firm's existing customers or markets. Integration and investigation of different sources of knowledge require a set of capabilities for an effective search, analysis, communication, and collaboration; highlighting the key role of technological capabilities (Wu et al., 2020).

Business value of IT (BVIT) research informs how firms rely on technological capabilities to manage complexity in organizational processes and improve the productivity of intra-firm and inter-firm knowledge works (Alharbi & Gregg, 2022; Cui et al., 2020; Joshi et al., 2010; Shekarian & Ramirez, 2022). IT-enabled capabilities enhance information processing capacity, communication among the firm's business units, and integration of external and internal knowledge sources (Joshi et al., 2010; Kleis et al., 2012). Innovation activities require a firm to have a high level of capacity for information processing. The knowledge involved in innovation is usually multidimensional and complex. Moreover, integrating, storing, processing, and distributing such knowledge can be costly and error-prone. Also, the process of product and service development has become data driven and data intensive (Wu et al., 2020). As such, a firm needs to build an effective infrastructure to facilitate collaboration, communication, and effective processing, analysis, and sharing of data. Technological capabilities allow a firm to integrate and harness external and internal knowledge sources within the firm's business processes (Joshi et al., 2010) as in the case of technology and improvements in the efficiency and speed of a firm's innovation process (Kleis et al., 2012). Also, IT-enabled capabilities can help a firm reduce uncertainty in business processes (Cui et al., 2020), thereby making decision making more effective and improving knowledge creation in the organization (Nonaka, 1994). A firm needs to integrate and process a high volume of information from internal and

external sources to stay competitive, reduce uncertainty, and make informed decisions for performance improvement. Firms can harness the scale of data available today by leveraging technological capabilities like analytics to improve productivity, pursue innovation, and transform business processes (Wu et al., 2020).

Also, R&D activities are considered inventive activities through which technological knowledge is created and scientific discoveries are made (Hall et al., 2013). Literature highlights the enabling role of investment in R&D activities, as a key organizational resource, for knowledge creation and performance impact (Havakhor et al., 2019; Kleis et al., 2012). R&D activities orient a firm to track the movements of competitors and the broader environment, providing the firm with better insights into new technologies, their potential, and how to implement them. Moreover, R&D resources provide a better understanding of innovative technologies that are currently used in one sector but may also be deployed in other sectors.

A successful BOD needs to acquire and develop certain capabilities such as effective communication, financial and market knowledge, technical competence, and leadership to effectively perform its governance role. Several organizational theories have been used to examine the role and impact of a BOD on organizational performance and knowledge creation, including the theories of agency, social network, real options, organizational control, stakeholder, human capital, and social capital (Balsmeier et al., 2017; Chang & Wu, 2021; Hendry & Kiel, 2004; Kor & Sundaramurthy, 2009; Lee et al., 2012). For example, Balsmeier et al. (2017) develop their arguments through the lens of agency theory and show that the intensified monitoring of a BOD leads to increased effort of a firm's executives as the agents, and this, in turn, increases the patenting of inventions. Chang and Wu (2021), through the lens of real options theory, argue that a greater information flow achieved through a BOD's network enables a BOD to effectively support and advise executives in adjusting investment portfolios and design a competitive investment strategy that creates a first-mover advantage, especially for new initiatives.

Social capital, in the context of a BOD, represents the assets created from the relationships between BOD members and external parties and the relationships among the BOD members themselves (Barroso-Castro et al., 2016). In our study, we use the theory of social capital to examine how the social capital of a BOD helps a firm access new types of information and resources to improve and optimize corporate decision making. We also examine how a more effective and optimized decision making process can improve the use of key organizational resources to provide more opportunities for innovation (Wincent et al., 2010).

3. Hypotheses

3.1. Direct effects of IT, R&D, and BOD social capital

In today's competitive market, a firm needs to constantly search for new sources of information to make informed decisions. A BOD, through its social capital, can provide a source for new and novel external information and knowledge, allowing the organization to maximize the utilization and returns of organizational resource investments. The informed organization can also enhance the quality and effectiveness of strategic decision making (Chang & Wu, 2021; Kim, 2005). For example, a firm with a high level of externalities, achieved through its BOD, can sense new changes in a market faster than its competitors. As a result, a firm may adjust business processes faster than its competitors and discover new opportunities in a market, resulting in first-mover product and service innovation and positive financial outcomes (Chen et al., 2016; Lee et al., 2012). The outside sources of knowledge that a BOD provides can also be a method for idea exchange and to create an innovation network (Wincent et al., 2010). Moreover, BOD social capital can improve the legitimacy of decisions made by a firm and strengthen a firm's public image. Legitimacy refers to the state where a firm's stakeholders such as customers, investors, and regulators perceive the firm's actions, within some socially constructed system of norms and values, as appropriate and find value in what the firm is doing (Hillman & Dalziel, 2003). This is important as a firm with higher legitimacy, achieved through a signal of its BOD reputation and network, may have better access to resources and a higher customer reception and awareness of its products, services, and business. This, in turn, can facilitate the completion of innovative initiatives or the introduction of new products and services to a market (Chuluun et al., 2017; Wincent et al., 2010).

In addition, a firm needs to adhere to accepted norms in a business environment and make adjustments if needed, like those related to corporate structure and financial policies (Chen et al., 2016). Especially due to public disclosure requirements, this becomes important and pushes a firm to constantly observe the corporate structure of its peers. A well-connected BOD can guide a firm to effectively align corporate level elements such as committee structure and policies (Chuluun et al., 2017; Kim, 2005). In addition, a BOD with higher social capital can enable

a firm to have a better understanding of norms in a business environment and adapt to a new change effectively (Barroso-Castro et al., 2016). Also, a BOD with high social capital can benefit more from the key external stakeholders of a firm. For example, investors seem to prefer to provide funding for a firm whose BOD has connections with reputable businesses (Kiel and Nicholson, 2006). This is critical for new innovative projects since such initiatives face more challenges in getting funding from external sources because of the nature of high uncertainty and information asymmetry (Kerr & Nanda, 2015). In such a situation, a BOD that is well-connected with banks can reduce information asymmetry and enable a firm to finance innovative projects that are risky, especially those projects with a high dependency on external capital (Chang & Wu, 2021). Therefore, we hypothesize:

H1a. *Higher BOD social capital is associated with an increase in the firm's innovation performance.*

Technology-enabled capabilities can help a firm acquire new external sources of knowledge, combine internal and external resources to build organizational capabilities, and assimilate those capabilities into business processes. In the context of a firm's innovation process, this can lead to higher innovation performance (Cui et al., 2020; Ravichandran et al., 2017). For instance, technology-enabled capabilities can contribute to process-level innovations through the mechanisms of management of knowledge assets, production support, and interorganizational coordination (Kleis et al., 2012). Also, IT-enabled knowledge capabilities can enhance various types of absorptive capacities in a firm, which in turn facilitate new product or service introduction and innovation (Joshi et al., 2010). Moreover, IT-enabled capabilities can improve the use of organizational resources by providing a higher information processing capability, better communication among a firm's units and employees, and a more effective integration of knowledge (Ravichandran et al., 2017).

R&D is important for firms as it enables new knowledge creation and improvement in existing business processes (Joshi et al., 2010). R&D resources are critical to fostering innovation in the organization. Because R&D resources enable a firm to create values by pursuing new methods in the development of products or services and identifying new opportunities in a market (Hall et al., 2013). R&D activities can even lead to a better competitive position as a firm can introduce new products or services to a market faster than its competitors (Havakhor et al., 2019). Consistent with prior work on the role of IT and R&D in organizational innovation (Hall et al., 2013; Havakhor et al., 2019; Kleis et al., 2012), we argue that IT and R&D resources enable a firm to improve the productivity of organizational innovation by integrating novel knowledge with the firm's existing ones or a novel way of integrating the firm's existing knowledge. Therefore, we hypothesize:

H1b. *Investment in IT is associated with an increase in the firm's innovation performance.*

H1c. *Investment in R&D is associated with an increase in the firm's innovation performance.*

3.2. Interaction effects of IT and R&D with BOD social capital

Agile and flexible board governance is critical for firm viability and shareholder value. The social capital of a BOD provides unique connections to influential and informed external actors, harnessing board member relationships to acquire rare and valuable resources (Barroso-Castro et al., 2016), including unique and exclusive information. BOD members can also seek out information regarding opportunities they know may bring short and long term benefits to the firm (Kor & Sundaramurthy, 2009). With insight into new innovations, for example, a firm can act swiftly to take advantage of an impending market change (Erhardt et al., 2003).

Through such unique resources and information, a BOD can guide what strategic decisions are possible and should be considered by an organization's executives. Such knowledge informs the IT and R&D investments that will be effective for a firm's corporate strategies, and the level of investment necessary for achieving its goals. Collectively, a BOD's external relationships provide insight and access to unique information, enabling higher effectiveness of IT and R&D resource investments and improve the return of each dollar invested. However, it should be noted that it is the level of diversity in a BOD's demographic characteristics and experience such as age, gender, and industry-specific knowledge that contributes to the breadth of information and hence to the unique character of that information (Johnson et al., 2013; Kor & Sundaramurthy, 2009).

There are also internal challenges to organizations that create a suboptimal flow of information, analysis results, and decisions that are presented to its BOD for BOD activities. The exponential increase in the amount and variety of data resulting from digitization (Kwon et al., 2014) and the processing of that data can be overwhelming. Incomplete or ineffective analysis impacts an executive's ability to make informed and timely strategic decisions. For example, new knowledge development, product innovation selection, or new markets to create or enter (Barroso-Castro et al., 2016; Chang & Wu, 2021). Decisions on

critical capital investments or the development of new supply chains can also suffer (Grover et al., 2018). As a result, a BOD may be acting upon suboptimal information and decisions brought to board meetings by a firm's executives.

Technological capabilities enable executive decision makers to quickly analyze multiple information sources, reduce uncertainty in decision making, and improve the quality of information brought to the board. Moreover, technological capabilities, by providing valuable insight and effective information processing, can help executives improve decision making interaction and coordination, leading to collective improvements across the firm (Grover et al., 2018). As a result, a BOD can improve its monitoring, service, and governance roles by having a more accurate and transparent picture of a firm's strategic goals, innovation pathways, and risk portfolio.

In sum, through technology-based improvements in decision making, a firm's executives can provide concise and actionable strategic insights for a BOD. A BOD can then utilize the insights to guide more effective corporate strategy, decision making, and innovation. As a result, a firm's executives can use organizational resources more effectively. Also, the valuable information brought by BOD to a firm provides unique inputs for technologies that, in turn, lead to improved decision making in the firm (Shekarian & Ramirez, 2021).

In addition, the social capital of BOD is a unique competence that can act as a labor market mechanism (Custódio et al., 2019) and improve a firm's tolerance for the failure of risky projects and push a firm to pursue innovation (Chang and Wu, 2021). This can be a critical factor in facilitating innovative activities as a firm's executives feel less pressure to allocate key organizational resources like those involved in IT and R&D areas to projects with high uncertainty, risk, and complexity. Moreover, a BOD through its networks and connections can go beyond a firm's knowledge boundaries to identify new innovative opportunities and types of strategic innovation within the current technological domain in the firm. This then allows for a higher return from IT and R&D investments.

Taken together, we argue that while IT and R&D activities improve a firm's value creation capability for new knowledge creation, a BOD can improve the effectiveness of such key organizational capabilities to pursue innovation. A BOD can provide a more effective resource guidance and support a firm's executives to pursue more risky projects, and this can lead to incremental and radical innovation impacts. Together, the interplay between BOD social capital and capabilities enabled by IT and R&D resources can be critical. Therefore, we hypothesize:

H2a. *The interplay between BOD social capital and IT can positively impact the firm's innovation performance.*

H2b. *The interplay between BOD social capital and R&D can positively impact the firm's innovation performance.*

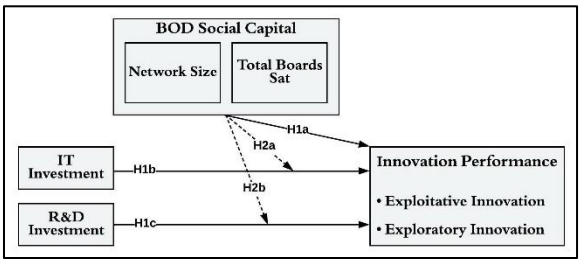

Figure 1. Research model

4. Methodology

4.1. Data and variables

We collect our firm-level research data from several sources. Technology data is sourced from Computer Intelligence Technology database (CITDB). Firm-level financial information and BOD measures are obtained from Wharton Research Data Service modules (WRDS). Also, innovation data is sourced from United States Patent and Trademark Office database (USPTO). Our integrated sample consists of 1,982 publicly traded US firms across thirteen years from 2005 to 2017 and eleven major sectors such as telecommunication services, materials, energy, and financials. Our sample contains publicly traded firms with at least one granted patent in the given time period.

Table 1 in the Appendix provides the description and summary statistics of variables. The dependent variables in our study are two innovation productivity measures that show a firm's innovation performance. Exploratory innovation (*ExplorInnov*) shows the number of firm's patents that are exploratory. A patent is considered as exploratory if at least 80% of its citations are based on the firm's new knowledge or not from the firm's existing knowledge. A firm's existing knowledge contains its granted patents and patents that the firm has cited in the last five years (Custódio et al., 2019). Exploitative innovation (*ExploitInnov*) shows the number of firm's patents that are exploitative. A patent is considered as exploitative if at least 80% of its citations are based on the firm's existing knowledge (Custódio et al., 2019). Network size (*NtwkSize*) is a dimension of BOD social capital. It represents a

BOD's external social capital and how influential it is. Total boards sat (*TotBrdSat*) is another dimension for BOD social capital. It shows the total number of boards a BOD has served in the given period. We measure IT investment (*ITInvst*) and R&D investment (*R&DInvst*) in million dollars. We control for size and type of a firm by using number of employees (FirmSize) and the scope of a firm's market (MultiNatl). Also, we control for advertising expense (*AdverExp*), total profit (*TotProfit*), and a firm's operating age (*FirmAge*). Additionally, we control for the type of industry a firm is operating by adding a dummy variable that shows if a firm's industry type is technology intensive or not (*TechIntnsv*). We determine technology-intensive industries by following Heckler's (2005) and Goldschlag and Miranda's (2020) works that rank industries by percent of employment in science, engineering, and technician occupations [1]. Prior research shows the positive impact of a BOD's characteristics on firm performance (Erhardt et al., 2003). Therefore, we add executive percentage (*ExePerc*) and time in company (*TimeInCo*) to control for a BOD's maturity. All correlations above an absolute value of 0.30 are significant at the 0.01 level.

4.2. Estimation equations

We employ an unbalanced panel dataset with 15,106 US firm observations from 2005 to 2017. We estimate the following equation:

$$Y_{i,t} = ßX_{i,t} + u_i + \varepsilon_{i,t} \quad \textbf{(1)}$$

Where Y represents a dependent variable such as exploratory innovation productivity; X is a vector of firm-level information such as firm profit, ßs are the coefficients; i shows a firm and t indicates time; u_i demonstrates random effects unobserved heterogeneity, and ε is the error term. Dependent, independent, and control variables are measured at the same time period.

Specifically, we use the following model to examine the direct effects of independent variables on innovation performance measures:

$$InnovPerf = ß_{10} + ß_{11}NtwkSize + ß_{12}TotBrdSat + ß_{13}ITInvst + ß_{14}R\&DInvst + ß_{1C}Controls_C + u_1 + \varepsilon_1 \quad \textbf{(2)}$$

We also use the following model to examine the interaction effects of independent variables on innovation performance measures:

$$InnovPerf = ß_{20} + ß_{21}NtwkSize + ß_{22}TotBrdSat + ß_{23}ITInvst + ß_{24}R\&DInvst + ß_{25}NtwkSize\times ITInvst + ß_{26}NtwkSize\times R\&DInvst + ß_{27}TotBrdSat\times ITInvst + ß_{28}TotBrdSat\times R\&DInvst + ß_{2C}Controls_C + u_2 + \varepsilon_2 \quad \textbf{(3)}$$

We use random effects (RE) for the estimation of our models since we have important time-invariant factors such as the firm's market scope (*MultiNatl*) and the firm's industry type (*TechIntnsv*). We check for the existence of homoscedasticity by using a Breusch-Pagan test and a White test in Stata. The result rejects the null hypothesis. Therefore, we cluster standard errors to address the heteroscedasticity concern (Wooldridge, 2016). We also check for potential multicollinearity using the VIF command in Stata. The highest value that the VIF test shows is 2.9. Also, the highest absolute value of any correlation among the explanatory variables is less than 0.50. Therefore, multicollinearity does not appear to be a concern for our analysis.

5. Results

Table 2 provides random effects estimation results for direct effects. As hypothesized in H1a, there is a significant and positive relationship between BOD social capital and innovation performance measures (Table 2, *NtwkSize* and *TotBrdSat* coefficients in columns 1 and 2). Therefore, a higher level of BOD social capital is associated with an increase in the firm's innovation performance, and **H1.a is supported**. Moreover, as hypothesized in H1.b, there is a significant and positive relationship between *ITInvst* and innovation performance measures (Table 2, *ITInvst* coefficients in columns 1 and 2). Therefore, a higher level of IT investment is associated with an increase in the firm's innovation performance, and **H1.b is supported**. Additionally, there is a significant and positive relationship between *R&DInvst* and innovation performance measures (Table 2, *R&DInvst* coefficients in columns 1 and 2). Therefore, a higher level of R&D investment is associated with an increase in the firm's innovation performance, and **H1.c is supported**. Consistent with existing research, the direct results indicate that IT and R&D activities, and a high level of BOD social capital are critical for the knowledge creation of a firm. These inputs enable a firm to utilize existing organizational knowledge or exploit new sources of information for innovation in products, services, and business processes.

Table 3 provides random effects estimation results for interaction effects. As hypothesized in H2, there is a significant and positive relationship between the combination of BOD social capital and IT investment with innovation performance measures (Table 3, *NtwkSize*×*ITInvst* and *TotBrdSat*×*ITInvst* coefficients in columns 1 and 2). Therefore, IT

[1] Hecker (2005) Table 4, pp. 64; Goldschlag & Miranda (2020) Appendix A, pp. 49.

complements BOD social capital for a positive innovation performance impact, and **H2a is supported.** While the combination of *NtwkSize×R&DInvst* leads to a higher innovation performance (Table 3, Columns 1 and 2), the combination of *TotBrdSat×R&DInvst* leads to a reduction in innovation performance (Table 3, Columns 1 and 2). Therefore, **H2b** about the combined effect of BOD social capital and R&D on a firm's innovation performance is **partially supported**. The negative combination of *R&D* and *TotBrdSat* may speak to the declining return when R&D efforts scale. Perhaps, other organizational resources as complementarities such as IT helps mitigate such negative outcomes, as shown by Ravichandran et al. (2017).

6. Discussion

6.1. Contributions

Our study contributes to the management and information systems research, extending prior work on the role of technological capabilities (Hall et al., 2013; Joshi et al., 2010; Kleis et al., 2012; Ravichandran et al., 2017) and BOD (Balsmeier et al., 2017; Chang & Wu, 2021; Chuluun et al., 2017; Kor & Sundaramurthy, 2009; Sierra-Morán et al., 2021) on organizational performance and knowledge creation outcomes.

To the best of our knowledge, this study is the first to conceptualize and empirically support the complementary role of a BOD in a more effective use of organizational resources for an innovation impact. Our study provides insight into how performance improvement and an effective knowledge creation can be driven through more effective governance, adding to literature that addresses the value of intangible firm factors like company culture, leadership skills, and commitment.

6.2. Limitations and future work

As is the case with any econometric research, our study has several limitations. Firstly, one has to be careful with interpreting the relationship between the social capital of BOD and investment in organizational resources with firm performance as a causal relationship since it is difficult to control for temporal precedence and alternative explanations in an observational study. Secondly, our archival data does not provide the detail of investment in IT and R&D resources. Perhaps, a survey of IT executives or organizational announcements can identify the key components of organizational investment. In addition, our sample only consists of publicly traded firms. This may limit the generalizability of our research implications, like for private firms. Future research can pursue other data sources to target private firms.

In future work, we will expand our examination of BOD, as a critical governance and strategic element, to identify other key dimensions of BOD that can improve and optimize the use of organizational resources for the new knowledge creation. We also perform an additional analysis to see how these relationships hold when organizational resources and aspects of a BOD are lagged. Moreover, we further examine the negative combination of R&D resources with BOD social capital to check for a potential U-shaped relationship (Ravichandran et al., 2017). Perhaps, a well-connected BOD can reduce the inefficiency of R&D activities when they scale.

6.3. Conclusion and implications

Using a panel dataset with 1,982 publicly traded US firms from 2005 to 2017, random effects estimation results show IT, R&D, and BOD social capital individually contribute to the firm innovation performance as reflected in exploitative and exploratory innovation productivity. Also, our results broadly indicate BOD social capital complements IT and R&D, as key organizational resources, to positively impact knowledge creation in the organization.

Our research offers new implications for IT business value research in organizational knowledge creation; particularly, our findings indicate the coexistence of IT and R&D resources, and a high level of BOD social capital is critical for the firm's new knowledge creation and innovation performance. Unique resources and an ability for information interpretation brought by a BOD can be harnessed by the firm's technological capabilities to become a component of decision making that brings forth the BOD guided change. In other words, a more effective organizational resource guidance enabled by a BOD can lead to incremental and radical innovation impacts. Also, a BOD can enhance a firm's tolerance for failure and provide support for executives to pursue innovative projects. Yet, many firms such as private companies do not have a BOD as a rule unless they are funded by private equity. Perhaps, such firms can replicate the benefits that a BOD potentially brings by constituting an advisory board.

7. References

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8. Appendix

Table 1. Description of variables

Variable	Description	Mean	SD	Source
Exploitative Innovation (ExploitInnov)	The logarithm of firm's exploitative patents. A patent is considered as exploitative if at least 80% of its citations are based on existing knowledge.	1.14	1.55	USPTO
Exploratory Innovation (ExplorInnov)	The logarithm of firm's exploratory patents. A patent is considered as exploratory if at least 80% of its citations are based on new knowledge.	1.22	1.51	USPTO
Network Size (NtwkSize)	It demonstrates the external social capital of BOD that is measured through the logarithm of the professional network of BOD members.	9.43	0.90	WRDS
Total Boards Sat (TotBrdSat)	The total number of boards a BOD has collectively served or serving.	61.17	32.89	WRDS
IT Investment (ITInvst)	The logarithm of firm's IT investment in million dollars.	2.36	1.78	CITBD
R&D Investment (R&DInvst)	The logarithm of firm's R&D investment in million dollars.	1.99	2.23	WRDS
Firm Size (FirmSize)	The logarithm of firm's employees.	7.98	2.24	WRDS
Advertising Expense (AdverExp)	The logarithm of firm's advertising expense in million dollars.	1.21	1.97	WRDS
MutltiNational Firm (MultiNatl)	If the firm's type is multinational: 1=Yes; 0=No.	0.46	0.50	CITBD
Firm Age (FirmAge)	The logarithm of firm's operating age.	3.09	1.55	CITBD
Total Profit (TotProfit)	The inverse hyperbolic sine of the firm's profit in million dollars.	6.19	2.95	WRDS
Technology Intensive Industry (TechIntnsv)	If the firm's industry type is technology intensive: 1=Yes; 0=No.	0.72	0.45	CITBD
Executive Percentage (ExePerc)	The proportion of executive directors; 100% is all executive members.	0.30	0.20	WRDS
Time in Company (TimeInCo)	The time BOD members have collectively been in the firm (in years).	86.18	50.96	WRDS

Table 2. Direct effect estimation results

	(1)	(2)
Variables	Exploit. Innov.	Explor. Innov.
NtwkSize	**0.036** (0.018)**	**0.044*** (0.016)**
TotBrdSat	**0.002** (0.001)**	**0.003** (0.001)**
ITInvst	**0.043*** (0.007)**	**0.017*** (0.006)**
R&DInvst	**0.223*** (0.018)**	**0.170*** (0.014)**
Controls	Yes	
Constant	-0.320** (0.164)	-0.216*** (0.150)
Observations	15,106	15,106
No. of Firms	1,982	1,982
Year	2005-2017	
R-Square	0.418	0.404

Robust standard errors in parentheses; *** p<0.01,** p<0.05, * p<0.1.

Table 3. Interaction effect estimation results

	(1)	(2)
Variables	Exploit. Innov.	Explor. Innov.
NtwkSize	0.084*** (0.023)	0.108*** (0.021)
TotBrdSat	0.001* (0.001)	0.001** (0.001)
ITInvst	0.033*** (0.007)	0.006 (0.006)
R&DInvst	0.219*** (0.017)	0.160*** (0.013)
NtwkSize×ITInvst	**0.010** (0.008)**	**0.010** (0.007)**
NtwkSize×R&DInvst	**0.043*** (0.011)**	**0.055*** (0.100)**
TotBrdSat×ITInvst	**0.003** (0.002)**	**0.001** (0.003)**
TotBrdSat×R&DInvst	**-0.002***(0.001)**	**-0.001** (0.001)**
Controls	Yes	
Constant	0.620*** (0.072)	0.597*** (0.077)
Observations	15,106	15,106
No. of Firms	1,982	1,982
Year	2005-2017	
R-Square	0.432	0.432