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RESEARCH ARTICLE

ATTENTION TO DIGITAL INNOVATION: EXPLORING THE IMPACT OF A CHIEF INFORMATION OFFICER IN THE TOP MANAGEMENT TEAM[1]

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We draw on the attention-based view of the firm to examine whether and when the presence of a CIO in the TMT has a positive effect on both firms' ideated digital innovation (IDI) (i.e., the intensity of firms' digital patenting activity) and commercialized digital innovation (CDI) (i.e., the digital sophistication of firms' new products). Building on the idea that attention processes are context dependent, we also explore the moderating roles of CEO characteristics (IT background and role tenure) as well as environmental characteristics (the industry's IT attention). We analyze data from a cross-industry panel of U.S. S&P 500 firms over eight years that includes up to 2,852 firm-year observations. The results indicate that CIO presence in the TMT is positively related to a firm's IDI and CDI. Furthermore, they show that the organizational context related to CEO characteristics moderates the CIO-CDI relationship and that the environmental context related to the industry's IT attention moderates the CIO-IDI relationship. Our research contributes to the information systems literature by providing robust evidence that CIO presence in the TMT positively influences a firm's digital innovation outcomes, showing how internal and external boundary conditions affect the work of CIOs, and elaborating the role of managerial attention as an underlying mechanism explaining digital innovation.

Keywords: Digital innovation, chief information officer, top management team, attention-based view

Introduction

Digital innovation, "the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology" (Nambisan et al., 2017, p. 224), has become a strategic priority for firms in technology-intensive industries and beyond (e.g., Fichman et al., 2014; Kohli & Melville, 2019; Nambisan et al., 2019). Digital technologies such as mobile devices, social media, artificial intelligence (AI), cloud computing, and blockchain are currently transforming entire industries by creating new business opportunities, changing the nature of competition, and causing disruption (Dewan & Ramaprasad, 2014; Gregory et al., 2021). For example, the disruptive nature of social media is currently forcing firms in the newspaper industry to rethink their business models (Karimi & Walter, 2015), software-driven innovation is shifting the gears of many manufacturing industries (Branstetter et al., 2019), and new digital developments by players such as Apple and Amazon are altering the music, film, and automotive industries (Dewan & Ramaprasad, 2014; Rahmati et al., 2020).

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Digitalization is even changing the nature of innovation itself, increasing its complexity, unpredictability, and scope. These changes raise the question of whether traditional approaches to innovation management can continue to be successful when it comes to digital innovation (e.g., Benner & Tushman, 2015; Nambisan et al., 2017, 2020).

To deal with this challenge and successfully innovate in the digital age, many firms are flattening their structures, implementing agile processes, and engaging in open innovation activities (e.g., Ramasubbu & Bardhan, 2021). Perhaps the most visible signal to internal and external stakeholders that a firm is committed to the digitalization of its processes, products, and business models is the creation of a senior executive position specifically dedicated to information technology (IT), the chief information officer (CIO) (Bendig et al., 2022). Previously seen as a technical figure with limited strategic focus, the CIO is now more likely to be a member of the top management team (TMT) (Banker et al., 2011; Liu & Preston, 2021).

The literature suggests that having a CIO in the TMT can strengthen a firm's IT competency, increase the efficiency of its digital processes and responsiveness to IT failures, and ultimately improve firm performance (e.g., Benaroch & Chernobai, 2017; Feng et al., 2021; Zafar et al., 2016). However, while studies provide valuable insights into the CIO role and factors influencing its effectiveness, important questions remain unanswered. Given that TMT members are responsible for a firm's strategic decisions and actions, it is particularly surprising that previous work has mainly linked CIO presence to operational rather than strategic activities. With a few exceptions, including Li et al.'s (2021) study on the relationship between CIO presence and firms' AI strategy, limited research has focused on how CIOs influence strategic decisions such as the initiation and implementation of digital innovation.

In this study, we draw on the attention-based view (ABV) of the firm to examine whether and when the presence of a CIO in the TMT has a positive effect on both firms' *ideated digital innovation* (IDI) (i.e., the intensity of firms' digital patenting activity) and *commercialized digital innovation* (CDI) (i.e., the digital sophistication of firms' new products). Introduced by Ocasio (1997), the ABV suggests that firm behavior (e.g., responses to environmental change and innovation decisions) is a function of the distribution and allocation of managerial attention, broadly defined as the "noticing, encoding, interpreting, and focusing of time and effort by organizational decision-makers" (Ocasio, 1997, p. 189). Given their power and influence, the chief executive officer (CEO) and other TMT members are seen as the most critical players when it comes to the regulation of attention in organizations (Gavetti et al., 2012). The characteristics and composition of the TMT not only influence what its members focus on and do (including which projects they initiate), but also channel the attention of lower-level managers and employees (Brielmaier & Friesl, 2022; Cho & Hambrick, 2006).

ABV research has found that the presence of certain figures in the TMT—chief marketing officer (Umashankar et al., 2022), chief sustainability officer (Fu et al., 2019), chief human resources officer (Lee, 2021)—shifts organizational attention to the issues corresponding to their roles. Similarly, we expect firms with a CIO in the TMT to place greater emphasis on digital technology. Building on the idea that managerial attention is situated in the particular organizational and environmental context (e.g., Brielmaier & Friesl, 2022; Ocasio, 1997), we also explore the moderating roles of CEO characteristics (i.e., IT background and role tenure) and industries' IT attention, as reflected in their firms' IT investment behavior. We expect that CIOs will find it easier to put digital innovation on the organizational agenda when the CEO is paying attention to similar issues and when growing attention towards IT in the industry suggests that the visibility of digital technologies to organizational decision makers and general awareness of their importance are high.

To test our hypotheses, we analyzed a cross-industry panel of U.S. Standard & Poor's (S&P) 500 firms over eight years. The results show that CIO presence in the TMT is positively related to both a firm's IDI and CDI. Our moderation analyses revealed an interesting pattern. On the one hand, we found that the CEO, as a player shaping organizational attention structures (Ocasio, 1997), has a moderating effect on the CIO-CDI relationship. While a CEO with an IT background can strengthen this relationship, the influence of a CIO on this market-based innovation outcome decreases with the CEO's role tenure. On the other hand, we found that environmental embeddedness (Ocasio, 1997) matters for IDI—i.e., the influence of a CIO on a firm's digital patenting activities is higher when the industry's IT attention is high.

This research contributes to information systems (IS) research in several meaningful ways. First, by providing evidence that CIO presence in the TMT positively influences a firm's digital innovation outcomes, our results add to the growing body of work on the role and impact of this important managerial position (e.g., Li et al., 2021; Zafar et al., 2016). While anecdotal evidence suggests that there is an ongoing evolution of the CIO position towards a more strategic role (see Liu & Preston, 2021), a limited number of studies have actually explored this core part of a CIO's job description empirically. Distinguishing between ideated and commercialized innovation (i.e., patents and new product introductions) (Joshi et al., 2010), our fine-grained analysis shows that by appointing a CIO to the TMT, firms can strengthen both the technological and market sides of their digital innovation strategy.

Second, our results provide new insights into the contingencies affecting the work of CIOs. Focusing on the moderating roles of CEO and industry characteristics, our study paints a nuanced picture of how internal attention structures and the broader external environment influence CIO-digital innovation linkages. Our observation that CEO characteristics act as moderators of the CIO-digital commercialized innovation relationship, whereas industry IT attention moderates the CIO-IDI relationship suggests that internal and contextual attention mechanisms differently influence the effectiveness of CIOs. Here, we also extend research on the interplay between the CIO and CEO (Banker et al., 2011; Benlian & Haffke, 2016) by showing that certain CEO attributes (i.e., an IT background) help CIOs promote digital innovation, whereas others (i.e., a long role tenure) act as barriers.

Finally, we contribute to the IS literature by elaborating the role of managerial attention as an underlying mechanism explaining digital innovation. While the ABV has been extensively used in fields such as strategy, marketing, and human resource management (e.g., Fu et al., 2019; Lee, 2021; Ocasio et al., 2018), IS research has paid less attention to this theoretical perspective. We argue that devoting more "attention to attention" may inform research on various topics in IS, including digital crowdfunding (Luo et al., 2022), AI (Li et al., 2021), and digital transformation (Singh & Hess, 2017). Indeed, Ocasio's (1997, p. 188) basic idea that "what decision makers do depends on what issues and answers they focus their attention on" is intuitively plausible and can help us understand digital transformation patterns.

Literature Review

In the early 1980s, the rise of IT and the growing awareness of its competitive potential led to the creation of the first CIO positions in organizations (e.g., Banker et al., 2011). Since then, more and more firms have appointed CIOs at different hierarchical levels and with varying responsibilities (Liu & Preston, 2021; Peppard, 2010). Correspondingly, there has been growing research interest in CIOs' characteristics (e.g., educational background, competencies, etc.), roles (e.g., technical, strategic, etc.), structural integration, and impact. A key contribution of the literature lies in elaborating the functional scope of the CIO role. Potential tasks of CIOs include but are not limited to managing the IT infrastructure (Smaltz et al., 2006), changing mindsets about data and IT (Chun & Mooney, 2009), realizing IT-enabled business opportunities (Chun & Mooney, 2009; Preston et al., 2008), building digital capabilities in the organization (Preston et al., 2008), developing agile infrastructures (Chen & Wu, 2011; Weill & Woerner, 2013), and advancing strategic change (Bendig et al., 2022). To position our study in the literature, Table 1 provides an overview of existing empirical research on the antecedents and consequences of CIO presence.

First, a number of studies contribute to a better understanding of factors explaining the creation of CIO positions in firms, showing that the attributes of decisions makers (e.g., CEO age; Karake, 1995), industry characteristics (e.g., industry IT intensity; Bendig et al., 2022), and certain events (e.g., IT failures; Benaroch & Chernobai, 2017) are among the factors that influence the likelihood of appointing a CIO. Second, there is evidence to suggest that CIO presence is positively related to operational efficiency (Benaroch & Chernobai, 2017) and firm performance (Feng et al., 2021; Zafar et al., 2016). Finally, a third category of studies focuses on the decisions and actions of CIOs that may explain these positive effects. For example, Turedi (2020) found that CIO presence predicts firms' IT investments, while Li et al. (2021) found that CIO presence predicts the strategic intention to apply AI (Li et al., 2021). Building on and extending these studies, we theorize how CIO presence in the TMT influences attention allocation in firms, thereby paving the way for digital innovation.

Theoretical Background

The ABV (Ocasio, 1997) serves as the overarching theory for our study. It draws on early works of the behavioral theory of the firm (e.g., Cyert & March, 1963; Simon, 1947) to suggest that individuals have limited attentional capabilities, a condition that is often termed as bounded rationality. Attention is a scarce resource, which organizational decision makers consciously and unconsciously manage by concentrating on certain issues, i.e., "the available repertoire of categories for making sense of the environment: problems, opportunities, and threats" and answers, i.e., "the available repertoire of action alternatives: proposals, routines, projects, programs, and procedures," while ignoring others (Ocasio, 1997, p. 189). Decision makers' foci of attention, the intensity with which they attend to certain issues, and the number of issues that they simultaneously focus on, explain their individual and organizational behavior (e.g., Brielmaier & Friesl, 2022). Empirical evidence supports this argument, as studies have shown that executive attention is a key mechanism influencing firms' innovation behavior (Eggers & Kaplan, 2009), responses to environmental events (Nadkarni & Barr, 2008), and sustainability performance (Ahn, 2020).

Table 1. Review of the CIO Presence Literature

Publication	Methodological approach	Research question(s)	Theoretical framework	Key findings
Karake (1995)	• Quant. cross-sectional design • 326 industrial firms listed in Fortune 500 • 1988 (+1987, 1986)	• What intraorganizational factors are associated with the creation of a CIO position on the top-level management team?	• Agency theory • Upper echelons theory	• TMT equity interests, number of outside directors on the board, and CEO's age and experience determine the appointment of a CIO to the TMT
Zafar et al. (2016)	• Quant. panel design • 439 firms • 2000 to 2010	• Is the presence of a CIO in the TMT an indicator of better management of information, when an organization is involved in an information security breach incident? • If so, does the impact of the CIO in the TMT differ by the confidentiality, integrity, and availability of security breaches?	• Upper echelons theory	• CIO presence has a positive impact on firm performance, especially in the context of security breach incidents • CIO presence is always positive regardless of the type of security breach • IT and business knowledge have a significant influence on firm performance
Benaroch and Chernobai (2017)	• Quant. panel design • U.S. publicly traded financial services firms • 1992 to 2009 • 110 operational IT failures • Event study	• Is the negative impact of operational IT failures on firms' market value a predictor of post-failure changes in the level of board IT competency? • What specific determinants of board IT competency are these changes associated with?	• IT governance • Agency theory • Resource dependence theory	• CIO presence enhances IT competency • Firms react to operational IT failures with board changes • IT improvements are proportional to the negative market reaction
Turedi (2020)	• Quant. panel design • Manufacturing firms listed on the U.S. and CDN stock exchanges • 125 firms • 2000 to 2012	• How does board monitoring influence firms' IT investment? • How does the presence of the CIO in a firm moderate the relationship between board monitoring and IT investment?	• Agency theory	• The ratio of outside directors positively influences IT investment • CIO presence weakens the relationship between the ratio of outside directors and IT investment • CIO presence has a positive direct effect on IT investment
Feng et al. (2021)	• Quant. panel design • 1,327 U.S. public firms from the Execucomp database • 2006 to 2015	• How is CIO structural power (including CIO presence) related to forward-looking firm performance? • How do internal and external factors moderate the relationship between CIO structural power and forward-looking firm performance?	• Resource-based view of the firm • TMT structural power framework	• CIO structural power is positively associated with forward-looking firm performance • The benefits of CIO structural power are higher under greater market turbulence, higher industry IT intensity, and greater operating efficiency
Li et al. (2021)	• Quant. cross-sectional design • 1,454 publicly listed firms in China • 2011 to 2015	• Can the presence of a CIO facilitate AI orientation in firms? • How do boards affect the relationship between the CIO and AI orientation?	• Upper echelons theory	• CIO presence in the TMT positively influences AI orientation • Board educational diversity, R&D experience, and AI experience positively moderate the CIO presence-AI orientation link

Bendig et al. (2022)	• Quant. panel design • 503 U.S. public firms • 2006 to 2017	• When and why are CIOs added to the top management team? • What is the impact of their presence on a firm's orientation towards exploration?	• Dynamic capabilities view of the firm • Dynamic managerial capabilities	• Environmental, strategic, and structural factors act as antecedents to the presence of CIOs in the TMT • CIO presence increases a firm's relative orientation toward exploration
This study	• Quant. panel design • 468/200 U.S. public firms • 2008 to 2015 • 2,852 and 1,225 firm-year observations • Data on more than 8,000 new product announcements and 2 million patents	• How does the presence of a CIO in the TMT affect firms' technological and market side of digital innovation? • How do the internal, organizational context and the external, environmental context affect these relationships?	• Attention-based view of the firm	• CIO presence in the TMT enhances firms' technological and market side of digital innovation • Industry IT attention strengthens the CIO presence-IDI link • CEO role tenure attenuates the CIO presence-CDI link

Table 2. The Three Principles of the Attention-Based View (Ocasio, 1997)

Principle	**Focus of attention**	**Situated attention**	**Structural distribution of attention**
Level attribute	***Individual cognition***	***Social context***	***Organizational structure***
Description	• Decision makers' focus is selective • Decision makers focus on a limited set of issues and answers • Decision makers' actions depend on the issues and answers they focus on	• Decision makers' foci on issues and answers, and the resulting actions they take, depend on the particular context they are located in • The characteristics of the situation describe the context • These characteristics pertain to (1) environmental stimuli and (2) organizational stimuli	• The decision context and decision makers' attention to it depend on how the organization distributes and controls the allocation of issues, answers, and decision makers within specific activities, communication, and procedures
Key concepts	• Selective attention leads to enhanced mindfulness of the object of attention or an idea • Controlled processing, i.e., learning new, is demanding, as action is triggered by mindfulness • Automatic processing, i.e., using known information, is less demanding, as it results in routinized actions	• Organizational context, i.e., internal stimuli such as characteristics of the TMT or the CEO • Environmental context, i.e., external stimuli such as market or technological dynamics • Consistency (or variance) in attention and behavior depends on the consistency (or variance) of the characteristics of the situation	• Attention structures generate values, channel decision-making into communications, and provide decision makers with structured sets of interests and identities • Economic and social structures (e.g., TMT and other teams) create, channel, and distribute attention • Focus of attention among organizational decision makers affects the resource allocation processes

How can firms shape the attention of their decision makers such that they act on behalf of the firm and contribute to desirable outcomes? While firms may channel and distribute the attention of their decision makers through formal goal setting, the ABV places emphasis on the roles of organizational attention structures and the context in which decision makers are embedded (Brielmaier & Friesl, 2022; Gavetti et al., 2012). In this context, Ocasio (1997) argues that organizational attention is a function of three interrelated principles: (1) focus of attention, (2) situated attention, and (3) structural distribution of attention depicted in Table 2.

First, the focus of attention relates to the individual-level cognition of decision makers, reflecting their personal interests, preferences, and perceptual biases (Ocasio, 1997). Decision makers' personal focus of attention is determined by, among other things, their values and personality, industry tenure, and functional background (Cho & Hambrick, 2006). Having a clear attentional focus helps decision makers perceive and act on the focal issue (e.g., sustainability, customer-centricity, digital innovation) rather than other issues (Ocasio, 1997).

Second, the notion of situated attention suggests that individuals' focus of attention may vary depending on the situation in which they find themselves (Brielmaier & Friesl, 2022; Cho & Hambrick, 2006). Accordingly, the characteristics of the decision-making situation, which is defined by both organizational and environmental stimuli, explain why decision makers focus on certain issues and engage in certain actions (Ocasio et al., 2018). A firm's current performance, which may be above or below its aspiration level, is an example of an internal situational factor regulating decision makers' attention, whereas environmental stimuli include industry characteristics (e.g., competitive intensity), market behavior (e.g., strategic moves by competitors), and external events more broadly (Brielmaier & Friesl, 2022; Fu et al., 2019).

Third, the ABV argues that structural features, here referred to as attention structures, play key roles in regulating and distributing the attention of decision makers. Ocasio (1997) posits four "attention regulators" that shape the situation decision makers find themselves in and how they attend to it: (1) the rules of the game (e.g., formal guidelines and informal principles of action), (2) the players (e.g., the CEO and other social actors), (3) the structural positions (e.g., formal roles and responsibilities), and (4) the resources (e.g., financial capital).

Building on these three principles of the ABV, we now develop hypotheses specifying how the presence of a CIO in the TMT affects a firm's digital innovation activities. According to the ABV, TMT members are key players that guide attention processes within the firm (Cho & Hambrick, 2006; Fu et al., 2019). CIOs matter when it comes to the initiation and implementation of digital innovation, both because they focus on IT-related issues and because they can influence other actors and frame decision-making processes.

Hypotheses

Our research model, based on the ABV, is presented in Figure 1. Hypotheses 1 and 2 link CIO presence to firms' IDI and CDI, respectively. Differentiating between ideated innovations (i.e., knowledge that is created through firms' innovation efforts and embodied in forms such as patents) and commercialized ones (i.e., new products that bring ideated innovations to the market) (Joshi et al., 2010, p. 476), we contribute to a nuanced understanding of the CIO's role in digital innovation processes. Our moderation hypotheses examine the influence of CEO (H3 and H4) and industry characteristics (H5) on these relationships, thereby accounting for the CEO's critical influence on attention processes within firms (Cho & Hambrick, 2006, Ocasio, 1997) as well as the environmental embeddedness of such processes (Brielmaier & Friesl, 2022; Nadkarni & Barr, 2008).

CIO Presence and Ideated Digital Innovation

First, we expect CIO presence in the TMT to influence the IDI of firms, as reflected in their patenting activities regarding digital technologies. Patent applications indicate that a firm is able to combine technical knowledge in significantly new, potentially value-generating ways (e.g., Cohen & Tripsas, 2018; Joshi et al., 2010). Wu et al. (2005, p. 863) therefore refer to patents as the "tangible embodiment of invention" and suggest that patenting activity is critical for firm survival in technology-intensive industries. Protecting technological inventions via patents can help firms successfully develop new products, appropriate the returns to their innovations, and realize other benefits such as greater strategic flexibility, better access to external financing, and additional income through licensing (e.g., Somaya, 2012).

Our assumption that CIOs play a role in firms' patenting activities is consistent with research showing that the characteristics of top managers and the composition of the TMT influence outcomes such as the number and impact of patents held by a firm (e.g., Choi et al., 2021; Liu et al., 2012; Wu et al., 2005). As members of the TMT, CIOs are powerful organizational actors who can promote the development of digital technologies (Benaroch & Chernobai, 2017; Chen et al., 2021). TMT membership places CIOs in a position in which they can provide leadership for invention (Wu et al., 2005), which may entail organizing the resources, support, and motivation necessary for digital innovation activities. Along with their positional power, CIOs possess expert power that is rooted in their educational background and professional experience (Carter et al., 2011). Job descriptions of CIOs generally stipulate that the candidates possess IT expertise, business knowledge, and strategic understanding (e.g., Liu & Preston, 2021). These qualities comprise a skill set that can help firms successfully apply for digital patents. The CIO position also has an important gatekeeper function, helping the firm to scan its environment for new developments in digital technologies and absorb related knowledge (Mitchell, 2006; Mithas et al., 2013). Here, the CIO's network and knowledge of the technological environment and the digital resources embedded in it are key factors influencing the firm's absorptive capacity (Hess et al., 2016).

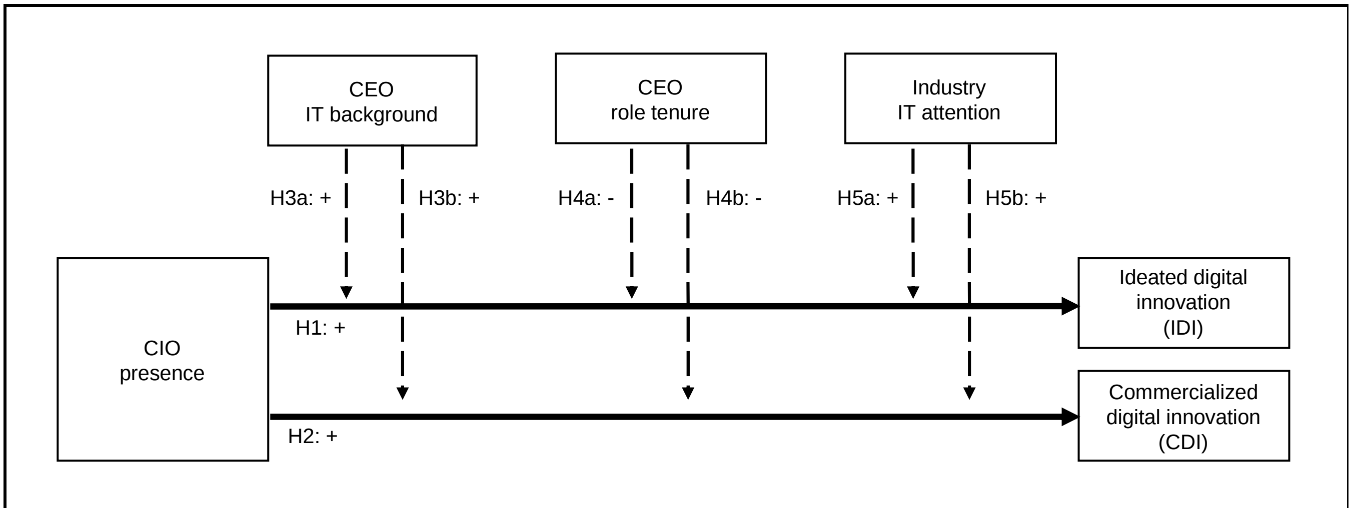

Figure 1. Research Model

Extending these arguments, we suggest that two attention-based mechanisms explain why having a CIO on the board strengthens a firm's IDI activities. The first mechanism, personal attention, refers to the principle of focus of attention outlined above (Ocasio, 1997). Depending on their education, functional background, experiences, values, and interests, decision makers hold different assumptions about the world, process and interpret information differently, and give a different meaning to events (e.g., Lee, 2021). Since most CIOs have an IT background, we expect them to pay close personal attention to issues and answers related to digital technologies, at the expense of other activities that do not appear on their mental radar. CIOs have a greater incentive to focus their time, energy, and effort on digital invention and other strategic issues versus operational tasks such as cost control, process efficiency, and data security (Peppard et al., 2011; Zafar et al., 2016). While focusing on innovation and strategic actions can help CIOs conform to role expectations (Banker et al., 2011), strategically important invention projects also represent a logical focus of attention because engaging in such projects may increase the CIO's legitimacy, influence, and visibility within the firm. Thus, CIOs are incentivized to support decisions that promote digital technologies they deem suitable for the organization whenever possible. Provided that CIOs possess sufficient discretion, as well as resources such as budget and staff members (Carpenter et al., 2004), they are also likely to initiate their own projects to invent new digital technologies.

The second mechanism explaining why the presence of a CIO in the TMT is beneficial to IDI, which we label structural attention, corresponds to the principle of structural distribution of attention suggested by the ABV (Ocasio, 1997). Adding a new position to the TMT changes the attention structure of the board, such that there will be a shift in the attentional focus toward the function of the newly appointed TMT member (Cho & Hambrick, 2006). Hence, bringing a CIO to the TMT shifts IT-related issues and answers from the periphery to the center of the firm's attention (Benaroch & Chernobai, 2017). Such a shift may foster the development of IT-related values in the firm, channel IT decision-making into communications, and provide decision makers with a structured set of IT-related interests and identities (Brielmaier & Friesl, 2022; Ocasio, 1997), each of which increases the likelihood that resources will be allocated to the development of digital technologies.

Appointing a CIO also serves as a strong signal to employees and stakeholders that IT is now at the center of the firm's strategic focus (Gavetti et al., 2012; Li et al., 2021). We argue that CIOs in the TMT trigger attention processes according to a trickle-down logic wherein the perceptions, attitudes, and behaviors of the CIO affect those of employees at lower hierarchical levels (Corwin et al., 2022). If a TMT member, in our case the CIO, deems a topic important, many other employees at different levels will also find the topic important and put it on their own agendas (Gunz & Jalland, 1996). The reason for this behavior is twofold. First, individuals are unconsciously influenced by the opinions of others, especially powerful actors who are part of the TMT. Second, individuals expect benefits, such as career progression, from jumping on the bandwagon (Raes et al., 2011; Ren & Guo, 2011). In summary, we hypothesize:

H1: *CIO presence in the TMT is positively associated with firms' IDI.*

CIO Presence and Commercialized Digital Innovation

A firm's ability to invent new digital technologies that are patentable is an important but not the only component of a successful digital innovation strategy. Joshi et al.'s (2010) distinction between ideated and commercialized innovation recognizes that patents need to be translated into market applications in the form of new products or services to realize their value-creation potential. We therefore examine whether CIO presence will affect the digital sophistication of a firm's new marketable products, which we refer to as CDI.

In general, the two mechanisms of personal and structural attention also explain why we expect firms with a CIO in the TMT to introduce new products to the market that are more digitally sophisticated than those of competitors that lack a CIO function at the strategy table. Regarding this market-oriented innovation activity, however, we suggest that the structural role of CIOs as attention regulators within the firm (see Ocasio, 1997) is more important. While CIOs in the TMT are powerful actors who, guided by their personal focus of attention, may initiate IT-related projects and develop digital technologies relatively autonomously (e.g., Benaroch & Chernobai, 2017), the development and market introduction of comprehensive digital products is much more complex. In fact, while digital inventions might be developed by an IT department alone, most product innovations emerge through cross-functional collaboration with multiple departments such as R&D, marketing, finance, operations, and IS (Khilji et al., 2006). This picture is complicated by the fact that different departments have conflicting interests and goals (e.g., cheap products vs. technological sophistication), which must be negotiated during the innovation process. Cyert and March (1963) describe organizations as being made up of actors and coalitions of actors who have diverging interests and compete for power. They suggest that such conflicts are resolved through compromise. This compromise is shaped by the interplay between power, politics, and attention (Gavetti et al., 2012)—fields in which the CIO's presence makes itself felt.

The question of what digital features a firm's products have is, after all, determined by internal decision-making and negotiation processes between the firm's departments (Yoo et al., 2012). The power of each department within these negotiations determines their ability to reach their goals, that is, to develop new products according to their preferences (Blagoeva et al., 2020; Hambrick, 2007). Based on the ABV (Brielmaier & Friesl, 2022; Ocasio, 1997), we argue that the appointment of a CIO represents a shift of attention to digital technologies and a shift of power toward the IT division. As noted above, the presence of CIOs in the TMT brings digital technologies and related entrepreneurial opportunities to the focus of attention of the TMT (Bendig et al., 2022; Li et al., 2021). Not least, being a member of the TMT, the firm's most powerful decision-making committee (Cannella et al., 2008; Carpenter et al., 2004), allows CIOs to more effectively build coalitions within the firm, thereby increasing their own bargaining power and ability to add digital features to new products. Hence, we hypothesize:

H2: *CIO presence in the TMT is positively associated with firms' CDI.*

The Role of Organizational and Environmental Contingencies

We adopt a contingency perspective on the relationship between CIO presence and digital innovation, arguing that organizational and environmental context factors influence a CIO's ability to promote digital innovation activities. Developing a contextualized understanding of this relationship is particularly important because there are conflicting arguments in the literature regarding the role and influence of CIOs, and because differences between IDI and CDI may mean that moderating mechanisms lead to distinct effects. The ABV's principle of situated attention, according to which decision makers' attention and behavior are shaped by the particular situation they find themselves in (Ocasio, 1997), provides the conceptual basis for our theorizing. Since the CEO is widely seen as an organization's most important decision maker (e.g., Cho & Hambrick, 2006), we first explore the moderating roles of CEOs' IT background and role tenure. We then turn to the environmental context in which decision makers are embedded as another important situational variable discussed in the ABV (Brielmaier & Friesl, 2022). In line with studies showing that attention allocation in organizations is shaped by the broader industry context (Cho & Hambrick, 2006; Nadkarni & Barr, 2008), we examine whether CIO effects are contingent on the general attention devoted to IT issues within an industry.

Internal Context Factors: CEO Characteristics

CEO IT Background

The CEO is typically the most powerful organizational actor in shaping the strategic agenda of the firm. As such, research adopting an ABV perspective has extensively studied the way the CEO's focus of attention influences organizational decisions and actions (e.g., Eggers & Kaplan, 2009) as well as the role of the CEO as an attention regulator influencing the attention of other decision makers (e.g., Ocasio & Joseph, 2008). This body of research suggests that CEOs' functional background influences how they interpret the environment, allocate their attention, and respond to identified issues. It is also assumed that their functional experiences determine how they interact with other organizational actors such as TMT members (Tuggle et al., 2010), which brings us to the interplay between the CEO and CIO.

We expect CIO presence in the TMT to have a stronger effect on firms' digital innovation activities when the CEO has an IT background. In general, having similar functional backgrounds increases the likelihood that the CEO and the CIO will share perceptions about the importance of certain problems and how to deal with them (Tuggle et al., 2010). Moreover, similarity effects suggest that CEOs tend to be biased towards executives with a similar background, as reflected in greater attention and support for them (e.g., Carpenter & Wade, 2002). For instance, a CEO with an IT background may give a CIO in the TMT more room to communicate IT-related issues and answers, thereby enhancing the visibility of the CIO's digital agenda in the organization (Kohli & Johnson, 2011). Thus, if a CEO has an IT background and the corresponding attentional focus, providing resources, influence, and legitimacy, the CIO will be better equipped to translate their own agenda—promoting digital innovation—into tangible outcomes. Along these lines, Leidner et al. (2010) argue that once two TMT members have a shared agenda, they are better able to mobilize the resources and power necessary to influence the organization's strategic direction.

We argue that an IT background on the part of the CEO strengthens the influence of the second mechanism through which CIO presence gives rise to digital innovation: structural attention. The CIO will be more effective in their functional role as an attention carrier in the TMT (Fu et al., 2019) if the CEO has a background in IT and thus a similar focus of attention. A shared attentional focus implies that CEOs and CIOs speak the same language, have similar goals, and send consistent signals about the development of digital technologies and products to members of the TMT (Fu et al., 2019; Lee, 2021) and other employees (Raes et al., 2011). If the communication of CIOs and CEOs with the rest of the company reflects similar personal agendas and focuses on the same issues and answers, we expect the aforementioned process of top-down attention diffusion in organizations to be reinforced (Corwin et al., 2022). Ocasio (1997) suggests that consistency (or, conversely, variance) in the attention and behavior of key players such as the CEO and CIO influences the extent to which organizational decision makers develop a shared understanding of the situation—specifically regarding what kinds of behaviors are expected, supported, and rewarded. When decision makers believe that digital innovation is not only high on the personal agenda of the CIO but also reflects the interests of the CEO, opportunism and bandwagon effects are likely, meaning that attention to digital technologies and products will trickle down to lower organizational levels.

Broad agreement across different hierarchical levels regarding the importance of digital technology is particularly important when it comes to the development and commercialization of digital products that require the collaboration of different departments. However, the arguments presented above similarly hold for patenting activities regarding digital technologies. Hence, we hypothesize:

H3a: *Having a CEO with an IT background reinforces the positive association between CIO presence and firms' IDI.*

H3b: *Having a CEO with an IT background reinforces the positive association between CIO presence and firms' CDI.*

CEO Role Tenure

While we expect that CEO IT background strengthens the relationship between CIO presence in the TMT and digital innovation, it is important to note that there are other characteristics of CEOs that may impede CIOs in their work—specifically in their ability to promote digital innovation. Seeking to provide a nuanced view of the influence of CEO characteristics on our main relationships, we introduce CEOs' role tenure (i.e., the time in this position) as a moderator that we expect attenuates the positive relationships between CIO presence and IDI, as well as CDI. In short, CEOs with a high role tenure are generally less open to shifting their focus of attention to new paradigms, procedures, and technologies (Hambrick & Fukutomi, 1991; Henderson et al., 2006). Over the years, they are also exposed to a growing number of issues and answers unrelated to digital technologies that may blur their focus of attention (Darouichi et al., 2021; Surroca et al., 2016).

First, empirical evidence supports the claim that with increasing role tenure CIOs pay less attention to innovation. For example, studies show that long CEO tenure tends to be negatively associated with firms' R&D spending (Barker III & Mueller, 2002) and inventiveness (i.e., the number of patents filed) (Wu et al., 2005). This body of work suggests that CEOs are less willing to take risks as their tenure increases (e.g., make major investments and engage in explorative innovation activities that may jeopardize the firm's current profitability) because they believe that they will not be able to reap the rewards of long-term oriented investments during their tenure (e.g., Barker III & Mueller, 2002). Job tenure is negatively related to individuals' future time perspective—that is, the perception of their remaining time in the job. A limited future time perspective of the CEO, in turn, undermines a firm's innovation activities in that such perceptions are associated with short-termism and a lack of strategic planning (see Rudolph et al., 2018). Long-tenured CEOs are more prone to be "stale in the saddle" (Miller, 1991, p. 34), which may entail a dysfunctional commitment to the paradigms that brought past successes at the expense of exploring alternative ways of doing things (Hambrick & Fukutomi, 1991; Wu et al, 2005). Picking up these arguments, we suggest that since CEOs with high role tenure will pay little attention to the development of digital technologies and products, their focus of attention will be diverted from the CIO's focus of attention. As discussed above, this makes it difficult for the CIO to influence the structural distribution of attention in a firm (Ocasio, 1997). When the CEO as the firm's key player signals that digital innovation is not a strategic priority, CIOs will struggle to shift the attention of other TMT members and lower-level employees in this direction (see Cho & Hambrick, 2006).

Second, even if long-tenured CEOs remain focused on innovation, which might be the case in highly dynamic industries (see Wu et al., 2005), they may suffer from a fragmentation of attention. During their tenure, long-serving CEOs experience changing environmental conditions, deal with a multitude of issues, and initiate various strategic initiatives (Darouichi et al., 2021; Surroca et al., 2016). With an increasing number of past experiences and activities that create (cognitive) path-dependencies and draw attentional resources, CEOs' attention to and support of new initiatives, including those of the CIO, can be expected to wane. Thus, broadening attention to a multitude of issues can overstrain the limited attentional resources of decision makers. When decision makers have to allocate their attention to multiple issues simultaneously, the intensity with which they attend to such stimuli is necessarily lower than it is when the agenda is narrower (e.g., Brielmaier & Friesl, 2022). Hambrick and Fukutomi's (1991) observation that CEOs' openness and responsiveness to new stimuli diminish in the late stages of their tenure can be interpreted as a reaction to attentional overload.

Based on these arguments, we conclude that CEOs with high tenure make it more difficult for CIOs to push the digital innovation agenda into TMTs and organizations. This applies to activities intended to promote the firms' IDI and CDI. Hence, we hypothesize:

H4a: *Having a CEO with high role tenure attenuates the positive association between CIO presence and firms' IDI.*

H4b: *Having a CEO with high role tenure attenuates the positive association between CIO presence and firms' CDI.*

External Context Factors: Industry IT Attention

In accordance with the principle of the situated attention of the ABV (Ocasio, 1997), studies have shown that environmental factors such as industry deregulation (Cho & Hambrick, 2006) and industry velocity (Nadkarni & Barr, 2008) influence organizational attention processes and outcomes. This research suggests that in order to adequately explain the allocation of attention within firms, it is necessary to consider the industry context in which they are embedded. Following this logic, we examine the moderating influence of an industry characteristic that may be particularly important in shaping decision makers' attention to digital innovation, namely the general attention towards IT in an industry. Conceptualized in terms of industry members' IT investment behavior, we expect industry IT attention to positively moderate the relationship between CIO presence and digital innovation. Two arguments support this claim.

First, we argue that high industry IT attention strengthens the mechanism of structural attention within firms. Accordingly, CIOs find it easier to shift the attention of organizational members to digital innovation and convince them to support their agenda if digital technologies and IT are highly visible or even institutionalized in the industry in which the firm operates (Hinings et al., 2018). In industries placing particular emphasis on IT, such as retail and financial services (see Bloom et al., 2012), the development of digital technologies and products is a generally accepted, expected, and often even taken-for-granted organizational activity that is seen as essential for firm survival (Burton Swanson & Ramiller, 1997; Hinings et al., 2018). The selective nature of attention processes means that the TMT and other key decision makers tend to focus their attention on issues and answers they deem important and with which they are familiar instead of other issues that are incongruent with their cognitive schemas (Ocasio, 1997). To some extent, members of an industry have a shared understanding of the issues that matter and recipes for success (Hoffman & Ocasio, 2001; Surroca et al., 2016). When the assumption that IT investments are a key driver of success is widely held in an industry, it is likely that organizational decision makers have a corresponding attentional orientation (see Cho & Hambrick, 2006). As discussed above, shared attention facilitates collective action—in this case, toward digital innovation.

Second, and related to this, research shows that decision makers attend to industry information and compare their firm with competitors, seeking confirmation that they are on the right path (Fernhaber & Li, 2013). The behavioral theory of the firm, which serves as the foundation of the ABV (Ocasio, 1997), has discussed such comparison processes under the heading of social aspirations. The notion of social aspirations suggests that decision makers compare the performance of their firm along different dimensions with the performance of a reference group of firms (Cyert & March, 1963). Given attentional limitations (Ocasio et al., 2018), managers will focus their attention on the social comparison information that is most present in their environment (Gavetti et al., 2012; Greve, 2008). In industries where investments in IT are common, this implies that managers other than the CIO focus their attention on related outcomes such as IDI and CDI when comparing their firm with others and setting goals (Dong, 2021). Situated attention to competing firms provides an explanation for mimetic behavior—that is, the tendency of firms to engage in activities similar to those of their peers, such as investing in the development of similar technologies and products (Fernhaber & Li, 2013).

Taken together, we argue that industries paying attention to IT provide a fertile ground for CIOs to positively influence both IDI and CDI. In these industries, the position of the CIO has greater legitimacy, and other TMT members, middle managers, and lower-level employees devote more attention to IT. Bendig et al.'s (2022) finding that firms in IT-intensive industries are more likely to appoint a CIO to the TMT than counterparts operating in less IT-oriented industries provides further support for this conclusion. Indeed, this indicates that there is a greater awareness of the importance of the CIO position in such industries. We hypothesize:

H5a: *Operating in industries with greater attention to IT reinforces the positive association between CIO presence and firms' IDI.*

H5b: *Operating in industries with greater attention to IT reinforces the positive association between CIO presence and firms' CDI.*

Data

Sample

The study's sample consists of U.S. firms included in the S&P 500 index between 2008 and 2015. We drew on firms' annual proxy statements filed with the U.S. Security and Exchange Commission (SEC), the BoardEx database, and other publicly available sources such as executives' official biographies and professional social network profiles to compile data on TMT and board members' roles (Nath & Bharadwaj, 2020). We used industry capital-spending data compiled by the U.S. Bureau of Economic Analysis (BEA) (Benaroch & Chernobai, 2017; U.S. Bureau of Economic Analysis, 2022) and financial data from S&P's Compustat North America and Compustat Segments. We collected patent data as of October 2019 from the PatentsView database provided by the U.S. Patent and Trademark Office (USPTO). We matched patent assignees to Compustat firms using a multi-stage fuzzy name matching algorithm. Since patents are often assigned to a firm's subsidiaries instead of the parent company, we identified each firm's subsidiaries, as listed in Exhibit 21 of the annual 10-K report (Alcácer et al., 2009) including each subsidiary per year in the observation period.

To determine firms' CDI, we restricted the sample to manufacturing firms with Standard Industrial Classification (SIC) codes 2000-3999 listed in the S&P 500 index. We focused on manufacturing firms to ensure that the management has direct control over distributed product innovations (in contrast to retail firms, who may announce products created by others) and to improve comparability in the coding process of the product announcements (Konchitchki & O'Leary, 2011). Further, we hand-collected more than 8,000 new product announcements in Business Wire, Newswire, and Thomson One via the Lexis Nexis database (Mudambi & Swift, 2014). Established protocols were used to collect and codify these product announcements (Chandy & Tellis, 1998; Mudambi & Swift, 2014). We used standardized search strings and included the lists of 10-K subsidiaries to identify relevant product announcements. We further cross-checked the results with press archives and other publicly available sources to ensure data quality and completeness.

We excluded firm-years for which we were unable to construct all measures. This procedure resulted in an unbalanced panel of 468 firms with 2,852 firm-years for the regressions analyzing the patent portfolio. In the regressions analyzing CDI, the sample included 200 firms with 1,225 firm-years.

Measures

Dependent Variables

We operationalized our first dependent variable, *IDI*, in terms of firms' patent applications. Patents have been frequently used to measure a firm's innovation output (see Savage et al., 2020 for a review). By representing the embodiment of new knowledge created through firms' innovation efforts, patents are ideal for capturing Joshi et al.'s (2010) notion of ideated innovation. We introduced a novel metric to measure a firm's digital innovation output by specifically analyzing a firm's patent applications that are related to information and communication technology. We started by determining the number of digital patents that a focal firm applied for in a given year. To identify digital patents, we selected subsections of the Cooperative Patent Classification (CPC) that are related to information and communication technology: G06—Computing, Calculating, Counting; G11—Information Storage; G16—Information and Communication Technology Adapted for Specific Application Fields; Y04—Information or Communication Technologies Having an Impact on Other Technology Areas. We followed the conceptualization of digital technology in prior literature as "information, computing, communication, and connectivity technologies" (Vial, 2019, p. 121). We then determined for each patent whether it was assigned by the patent examiner to one of these CPC subsections and used this information to construct a binary digital indicator.

We dated patents according to the year the patent application was filed rather than the year the patent was granted for two reasons. First, the application date is a better proxy of the actual timing of the patented invention since inventors have a strong incentive to apply as soon as possible (Custódio et al., 2019), whereas the grant date depends on the Patent Office review process (Alcácer & Gittelman, 2006). Second, we can reasonably assume that the scope and direction of patenting activity can still be affected by the CIO at the time of the application. By using the application rather than the grant year, we align our research with that of earlier scholars (Custódio et al., 2019; Hall et al., 2001; Sunder et al., 2017; Wu et al., 2005).

Finding that 80% of all patents were granted within four years in our data set, we followed prior remedies to address time truncation (Custódio et al., 2019; Hall et al., 2001). First, we ended our sample in 2015, four years before the latest data available. Second, we adjusted the patent application count for each year using the average lag distribution observed in our sample. Third, we included year fixed effects in our regressions to address remaining potential time truncation issues. To determine *IDI*, we divided a firm's number of digital patent applications by the firm's total number of patent applications in a year. The metric is therefore a fraction bounded between zero and one. This percentage reflects the technological priorities a firm has set in its patent portfolio.

The second dependent variable, *CDI*, is an output-oriented measure of commercialized product innovation (see Joshi et al., 2010). New product announcements have been frequently used in innovation research to operationalize customer-facing innovation (Chandy & Tellis, 1998; Mudambi & Swift, 2014; Rubera & Kirca, 2012). Moreover, they are instruments of external corporate communication that provide researchers with an unobtrusive way to gather valuable data on firms' innovation activities and priorities (Robertson et al., 1995; Sorescu et al., 2007).

To determine a new product announcement's level of digital sophistication relative to the current market standard, we adapted the classification logic from Chandy and Tellis (2000): A team of experts examined each new product announcement using a consistent approach. The experts were asked to assess the following question on a 9-point scale: "Is the product substantially more digitally sophisticated than its predecessor?," where 1 corresponds to "equally or less digitally sophisticated" and 9 corresponds to "substantially more digitally sophisticated." For this assessment, the experts were provided with five guiding questions based on the layered architecture of digital technology concept of Yoo et al. (2010) (see Table 3).

To ensure consistency and rigor, three experts coded each product announcement independently; all were extensively trained so that their coding approaches were as similar and consistent as possible. We investigated product announcements with divergent assessments and asked the experts to conduct additional research on technologies and market standards to verify their assessment where necessary. To assess the quality of the rating process, we determined interrater reliability using the r_{WG} index (Newman & Sin, 2020), which evaluates the observed versus the expected variation of the coding results using the following formula:

$$r_{WG} = 1 - \frac{var(observed)}{var(expected)} = 1 - \frac{s_{xj}^2}{\sigma_{null}^2}$$

where s_{xj}^2 is the empirical variation in the three raters' assessment of new product announcements, while σ_{null}^2 is the expected variation of the coding, assuming zero agreement. Despite the large sample and the wide range of products and industries covered, we found that the r_{WG} index ranges from 0.8 to 1.0, with an average of 0.95, which is higher than the threshold of 0.7 proposed in prior literature (Burke et al., 1999). Subsequently, the products referred to in the announcements were categorized as significantly more digitally sophisticated than their predecessors if the average rating of all three experts was at least five on the 9-point scale. To determine *CDI*, we divided the digital new product announcements by the firm's total number of new product announcements in a year, which again yielded a fraction.

Independent Variable

To identify CIOs in the TMT, we followed recent TMT research (Benaroch & Chernobai, 2017; Bendig et al., 2022; Nath & Bharadwaj, 2020). First, we defined the firm's TMT as those executive officers of the registrant named in the firm's annual proxy statements. This definition of the TMT usually includes the CEO, the vice presidents in charge of principal business units or divisions, and the executives in charge of central functions, such as the chief financial officer and the CIO. We therefore included officers based on the firms' classification of senior executives with policy-making responsibilities in their organization. Second, we searched the executives' titles for specific keywords proposed in prior research (Menz, 2012). Since CIOs often carry different titles (Banker et al., 2011), executives' role descriptions in various sources were further analyzed to determine their specific responsibilities. The resulting binary variable, *CIO presence*, indicated whether the firm had a CIO in its TMT. We found that roughly 20% of the firms in our sample had a CIO in their TMT.

Table 3. Assessing Digital Sophistication of New Product Announcements (Yoo et al., 2010)		
#	**Dimension**	**Guiding question**
1	Device layer	Does the product consist of a physical machine layer as hardware and a logical capability as an operating system, whereby it enables physical machines to connect to other layers?
2	Network layer	Does the product contain a network layer (physical or logical) that facilitates the device to connect to other devices?
3	Service layer	Does the product include a service layer represented by a user application?
4	Content layer	Does the product enable data to be shared or stored?
5	Generativity	Is the product designed as a platform that can attract heterogeneous and unexpected components belonging to different design hierarchies, i.e., is the product open to be utilized as a component for non-company products?

Moderator Variables

First, to operationalize *CEO IT background*, we collected each CEO's prior work history and constructed a binary variable indicating whether they had previously held an executive position in an IT-related industry, as identified by the respective firms' industry codes, following Kor and Sundaramurthy (2009). We considered SIC codes 357, 366, 367, 48, and 737 to be IT-related industries. Prior work history has frequently been used as a proxy for an executive's expertise in a certain topic (e.g., Kor & Sundaramurthy, 2009). Second, to operationalize *CEO role tenure*, we determined the number of years since a CEO was appointed to their current role at their current firm (following Hirshleifer et al., 2012; Sunder et al., 2017).

Third, to operationalize *industry IT attention* we built on shifts in industry-level IT investment data. Drawing on annual economic capital-spending data per three-digit North American Industry Classification System (NAICS) group level provided by the BEA, we suggest that an industry's attention to IT is reflected in the proportion of capital spending increases in IT-related investment categories. Consistent with prior research, our measure captures the following IT-related investment categories: Mainframes, personal computers, direct-access storage devices, printers, terminals, tape drives, storage devices, system integrators, communications, prepackaged software, custom software, and own-account software (Benaroch & Chernobai, 2017; Kim & Brynjolfsson, 2009). The variable *industry IT attention* was thus calculated as the average year-to-year change in the share of capital spending in these investment categories over the previous three years. A high score indicates that in this industry, the executives' focus of attention has shifted toward IT, which is reflected in the increasing share of IT investments made by their firms.

Control Variables

In the regressions, we controlled for several firm- and top management team-level characteristics. Table 4 summarizes the variable definitions and data sources.

Analysis and Results

Estimation Procedures

As an exclusion restriction for the first stage of our models, we used firms' R&D stock intensity. Prior studies have found that the decision to patent depends largely on a firm's R&D effort (Arora & Ceccagnoli, 2006; Griliches et al., 1991). We contend that the same argument holds for commercialized product innovations. We assumed that R&D stock intensity is directly related to the decision to file patent applications or release product announcements, but that R&D stock intensity is only related to the relative share of digital patents and products through the participation decision (Wulff, 2019). In constrast, Bharadwaj et al. (2013) argue that digitalization choices are strongly driven by external and internal IT trends. According to the Statement of Financial Accounting Standards No. 2, R&D expenditure excludes several items related to IT (purchased software, engineering expense, software expense for firms with software revenues), inventor royalties, and market research and testing. It is therefore unlikely that our instrument, Compustat's R&D stock intensity of a firm, correlates with IT trends in the market (e.g., cloud computing, big data) or IT trends in the firm (e.g., mandate for IT by the CIO) (Bharadwaj et al., 2013). Furthermore, we employed R&D stock over time to calculate our measure, which was less affected by short-term trends than annual expenditure levels. Since the fit of an exclusion restriction cannot be tested empirically, we also offer a single-stage model to mitigate a potentially biased model.

We measured *firm R&D stock intensity* as the accumulated R&D stock divided by sales. Following Hall (1990), R&D stock K in year t is defined as $K_t = K_{t-1} (1 - \delta) + R_t$, where R_t is the R&D expenditure and the depreciation rate δ is 0.15. Firm-years with missing R&D expenditure were assigned a value of zero (Sunder et al., 2017). Further, we estimated firm-clustered robust standard errors. We also included year fixed effects to control for time trends and industry fixed effects on the two-digit NAICS level to control for industry patterns in our analysis. All continuous variables were winsorized at the 1% and 99% levels to mitigate outlier effects. To address reverse causality, we lagged all explanatory variables by one year.

Table 4. Variable Definitions and Data Sources

Variable	Description	Data source
(1) IDI	Ideated digital innovation (IDI): Firm's number of digital patent applications divided by the firm's total number of patent applications (see Branstetter et al., 2019)	Patentsview (USPTO)
(2) CDI	Commercialized digital innovation (CDI): Firm's number of product announcements with products rated as more digitally sophisticated than existing products on the market divided by total product announcements (see Chandy & Tellis, 1998)	Nexis
(3) Patenting	Binary variable indicating whether a firm has (1) or has not (0) filed a patent application in the focal year, required as the indicator variable in the first-stage model	Constructed from USPTO dataset
(4) Announcing	Binary variable indicating whether a firm has (1) or has not (0) released a product announcement in the focal year, required as the indicator variable in the first-stage model	Constructed from Nexis dataset
(5) CIO presence	Binary variable indicating CIO presence among the senior executives mentioned in the firm's proxy statements (see Benaroch & Chernobai, 2017)	SEC proxy filings from EDGAR
(6) CEO IT background	Binary variable indicating whether a CEO has previously held an executive position in an IT-related industry as identified by the respective firms' industry codes (see Kor & Sundaramurthy, 2009)	Annual reports and public profiles
(7) CEO role tenure	Number of years since a chief executive officer (CEO) was appointed to their current role at the current firm (see Hirshleifer et al., 2012; Sunder et al., 2017)	Annual reports and public profiles
(8) Industry IT attention	Average year-to-year change per industry in the share of capital spending in IT-related investment categories in the previous three years (see Benaroch & Chernobai, 2017; Kim & Brynjolfsson, 2009)	BEA
(9) Firm R&D stock intensity	Accumulated research & development (R&D) stock divided by sales; R&D stock *K* in year *t* is defined as $K_t = K_{t-1} (1 - \delta) + R_t$ where R_t is the R&D expenditure and the depreciation rate δ is 0.15; firm-years with missing R&D expenditure are assigned a zero value (see Hall, 1990; Sunder et al., 2017)	Compustat
(10) Firm size	Natural logarithm of total sales (see Custódio et al., 2019; Hirshleifer et al., 2012)	Compustat
(11) Firm capital intensity	Net property, plant & equipment divided by the number of employees (see Hirshleifer et al., 2012; Sunder et al., 2017)	Compustat
(12) Firm leverage	Total long-term debt divided by total assets (see Custódio et al., 2019; Hirshleifer et al., 2012)	Compustat
(13) Firm performance	Market value of equity divided by total assets minus total liabilities (see Choi et al., 2021)	Compustat
(14) Firm segments	Number of business segments reported in annual statements (see Hirshleifer et al., 2012)	Compustat
(15) Firm IT segment share	Share of revenue in Compustat Segments linked to IT-related business segments (SIC codes 357, 366, 367, 48, and 737) (see Bendig et al., 2022)	Compustat Segments
(16) CEO duality	Coded as 1 if the CEO is also the chairman of the board, 0 otherwise (see Benaroch & Chernobai, 2017)	BoardEx
(17) TMT size	Top management team (TMT) size: Total number of senior executives mentioned in the firm's annual proxy statements (10K or DEF 14A)	SEC proxy filings from EDGAR
(18) Independent director share	Proportion of independent directors on the board (see Benaroch & Chernobai, 2017)	BoardEx

Note: USPTO: U.S. Patent and Trademark Office; SEC: U.S. Securities and Exchange Commission; BEA: U.S. Bureau of Economic Analysis

Hypothesis Tests

Table 5 presents the descriptive statistics and bivariate correlations of the variables in our model. We found that none of the pairwise correlation coefficients exceed |0.45| and that none of the variance inflation factors (VIFs) exceed 1.52. Our results remained robust across all models and we did not detect indicators of multicollinearity, as described by Kalnins (2018). We thus infer that multicollinearity is not likely an issue of concern.

Tables 6 and 7 present the results for the dependent variables *IDI* and *CDI*, respectively. In the first column, labeled Binary model, each table introduces the first-stage Tobit model predicting whether firms apply for patents or release product announcements at all. The coefficient for firm *R&D stock intensity* is statistically significant and positive in both models, indicating that it is a suitable exclusion restriction ($p < 0.05$). We also found that R&D stock intensity is not a statistically significant direct predictor of both dependent variables in a simplified single-stage model (see Table A2, Models 1 and 2 in the Appendix).

Tables 6 and 7 also successively present results by adding the relevant variables step by step. Regarding H1, *CIO presence* has a positive and statistically significant impact on *IDI* ($\beta = 0.314$, $p = 0.001$, 95% confidence intervals (95% CI) = [0.135; 0.492] in Model 2, Table 6; and $\beta = 0.369$, $p = 0.012$, 95% CI = [0.082; 0.656] in Model 6, Table 6). A pairwise comparison of predictive margins indicates a 4.3 percentage point difference ($p < 0.01$) in the digital patent application share between firms with and without a CIO in their TMT. Regarding H2, we found that *CIO presence* has a positive and statistically significant impact on *CDI* ($\beta = 0.357$, $p = 0.032$, 95% CI = [0.031; 0.684] in Model 2, Table 7; and $\beta = 0.556$, $p = 0.014$, 95% CI = [0.113; 0.999] in Model 6, Table 7). A pairwise comparison of predictive margins indicates a 3.2 percentage point difference ($p = 0.12$) in digital product announcement share between firms with and without a CIO in their TMT. Our findings hence support H1 and H2.

Table 5. Descriptive Sample Statistics and Bivariate Correlation Coefficients

Variables	Min	Mean	Max	*SD*	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) Ideated digital innovation	0.00	0.20	1.00	0.33																	
(2) Commercialized digital innovation	0.00	0.03	1.00	0.13	0.01																
(3) Patenting	0.00	0.70	1.00	0.46	**0.39**	**0.14**															
(4) Announcing	0.00	0.28	1.00	0.45	**-0.13**	**0.38**	**0.33**														
(5) CIO presence	0.00	0.20	1.00	0.4	**0.12**	**0.07**	0	-0.01													
(6) CEO IT background	0.00	0.22	1.00	0.41	**0.32**	**0.08**	**0.24**	**0.09**	-0.03												
(7) CEO role tenure	0.00	5.98	51.00	6.29	-0.01	-0.01	**-0.09**	**-0.08**	**-0.05**	-0.03											
(8) Industry IT attention	-0.06	0.00	0.06	0.01	**0.04**	**-0.08**	**-0.11**	**-0.18**	**0.07**	**-0.13**	**-0.05**										
(9) Firm R&D stock intensity	0.00	0.32	1.47	0.07	**0.1**	**0.1**	**0.29**	**0.31**	**-0.07**	**0.32**	-0.01	**-0.17**									
(10) Firm size[a]	878	17,369	136,016	24,580	**0.08**	0.03	**0.15**	-0.02	**0.07**	**-0.07**	0	0.03	**-0.17**								
(11) Firm capital intensity	0.85	531.06	1,255.73	7,155.50	**-0.19**	**-0.09**	**-0.31**	**-0.21**	**-0.08**	**-0.14**	-0.03	-0.02	**-0.15**	**-0.1**							
(12) Firm leverage	0.00	0.23	1.39	0.14	**-0.2**	**-0.06**	**-0.1**	**-0.04**	-0.01	**-0.05**	-0.01	-0.01	**-0.14**	**-0.11**	**0.12**						
(13) Firm performance	-28.66	3.32	44.11	5.91	-0.01	0.03	0.04	**0.07**	0.02	0.01	0.03	**-0.07**	**0.1**	-0.02	**-0.08**	**0.05**					
(14) Firm segments	1.00	11.54	55.00	6.61	-0.03	**0.07**	**0.11**	0.04	**-0.08**	**-0.07**	**-0.04**	-0.01	**-0.17**	**0.31**	**-0.07**	-0.02	**-0.04**				
(15) Firm IT segment share	0.00	0.07	1.00	0.23	**0.45**	**0.08**	**0.17**	-0.01	-0.01	**0.45**	-0.04	**-0.1**	**0.26**	**-0.1**	**-0.12**	**-0.11**	0.02	**-0.08**			
(16) CEO duality	0.00	0.04	1.00	0.21	**-0.05**	**0.05**	**0.05**	**0.08**	0.02	0	0.03	-0.01	0	**-0.07**	0	0	-0.01	0.02	-0.01		
(17) TMT size	3.00	10.71	38.00	4.38	-0.03	**0.06**	**0.05**	**0.1**	**0.28**	**-0.08**	**-0.05**	0.03	**-0.04**	**0.28**	-0.01	**-0.09**	-0.01	**0.12**	**-0.09**	**-0.04**	
(18) Independent director share	0.00	0.85	1.00	0.16	0	-0.02	**0.04**	-0.01	0.03	0	**-0.15**	0.01	0.01	**0.07**	**0.05**	**0.06**	0.03	-0.04	-0.02	**0.33**	**0.05**

Note: All independent and control variables are lagged by one year. All continuous variables are winsorized at the 1% and 99% levels. Statistically significant correlations ($p < 0.05$; two-tailed tests) are highlighted in bold. *SD*: standard deviation. $n = 2,852$. For this analysis, we replace missing values of CDI with zero. n = 1,225 when analyzing CDI. [a] Figures are given in millions of U.S. dollars without log.

Table 6. Results of Generalized Two-Stage Fractional Regression Models (GTP-FRM) with Ideated Digital Innovation as the Dependent Variable (DV)

Variables	1st stage DV: *Patenting*	2nd stage DV: *Ideated digital innovation (IDI)*					
	Binary model	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
CIO presence			0.314*** (0.091)	0.421*** (0.111)	0.289* (0.124)	0.287** (0.092)	0.369* (0.147)
CIO presence × CEO IT background				-0.330* (0.167)			-0.309 † (0.167)
CIO presence × CEO role tenure					0.005 (0.016)		0.004 (0.016)
CIO presence × Industry IT attention						17.383** (5.451)	17.034** (5.417)
Firm R&D stock intensity	50.953* (25.242)						
CEO IT background	0.578* (0.234)	0.375*** (0.102)	0.380*** (0.103)	0.452*** (0.111)	0.381*** (0.103)	0.377*** (0.102)	0.444*** (0.109)
CEO role tenure	-0.004 (0.011)	0.005 (0.008)	0.006 (0.008)	0.007 (0.008)	0.006 (0.008)	0.006 (0.008)	0.005 (0.008)
Industry IT attention	-2.931 (3.814)	-5.319* (2.390)	-6.021* (2.438)	-5.845* (2.440)	-6.000* (2.430)	-10.700*** (3.048)	-10.388*** (3.026)
Firm size	0.553*** (0.078)	0.027 (0.064)	0.025 (0.061)	0.022 (0.061)	0.025 (0.061)	0.025 (0.061)	0.023 (0.061)
Firm capital intensity	0.000† (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Firm leverage	0.684 (0.486)	-1.145*** (0.318)	-1.234*** (0.317)	-1.230*** (0.313)	-1.232*** (0.316)	-1.214*** (0.311)	-1.211*** (0.308)
Firm performance	-0.005 (0.005)	0.005 (0.003)	0.004 (0.003)	0.005 (0.003)	0.005 (0.004)	0.005 (0.003)	0.005 (0.003)
Firm segments	0.012 (0.011)	-0.013 (0.009)	-0.011 (0.008)	-0.010 (0.008)	-0.011 (0.008)	-0.011 (0.008)	-0.009 (0.008)
Firm IT segment share	0.918* (0.438)	1.094*** (0.199)	1.075*** (0.196)	1.054*** (0.195)	1.075*** (0.196)	1.059*** (0.196)	1.041*** (0.195)
CEO duality	0.475† (0.251)	-0.165 (0.182)	-0.172 (0.177)	-0.156 (0.178)	-0.170 (0.177)	-0.176 (0.173)	-0.159 (0.173)
TMT size	-0.012 (0.017)	-0.001 (0.010)	-0.011 (0.010)	-0.012 (0.010)	-0.011 (0.010)	-0.010 (0.010)	-0.011 (0.010)
Independent director share	0.424 (0.349)	-0.088 (0.392)	-0.098 (0.384)	-0.064 (0.384)	-0.096 (0.383)	-0.129 (0.374)	-0.096 (0.374)
Constant	-5.474*** (0.738)	-1.726* (0.766)	-1.633* (0.749)	-1.662* (0.758)	-1.639* (0.751)	-1.642* (0.749)	-1.673* (0.759)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2,852	2,852	2,852	2,852	2,852	2,852	2,852
Chi²		1181.879	1237.52	1270.648	1238.987	1239.607	1276.663
AIC		3519.471	3511.154	3510.398	3513.088	3506.675	3508.228
BIC		3960.198	3957.837	3963.037	3965.727	3959.314	3972.779

Note: All independent and control variables are lagged by one year. All continuous variables are winsorized at the 1% and 99% levels. Firm size is log-transformed. Firm-clustered robust standard errors in parentheses. † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.; *** $p < 0.001$

Table 7. Results of Generalized Two-Stage Fractional Regression Models (GTP-FRM) with Commercialized Digital Innovation as the Dependent Variable (DV)

Variables	1st stage DV: *Announcing*	2nd stage DV: *Commercialized digital innovation (CDI)*					
	Binary model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
CIO presence			0.357* (0.167)	0.268 (0.181)	0.628** (0.212)	0.391* (0.172)	0.556* (0.226)
CIO presence × CEO IT background				0.358 (0.245)			0.469* (0.234)
CIO presence × CEO role tenure					-0.065** (0.025)		-0.067** 0.024
CIO presence × Industry IT attention						21.920 (14.370)	25.743† (15.351)
Firm R&D stock intensity	1.804* (0.880)						
CEO IT background	0.226 (0.184)	-0.012 (0.207)	-0.015 (0.183)	-0.105 (0.188)	-0.011 (0.182)	-0.010 (0.170)	-0.117 (0.170)
CEO role tenure	-0.006 (0.011)	0.020† (0.011)	0.024* (0.010)	0.024* (0.010)	0.034*** (0.010)	0.023* (0.010)	0.032** (0.010)
Industry IT attention	5.365 (8.090)	2.500 (7.811)	-0.708 (7.036)	-0.594 (7.050)	-0.149 (7.150)	-3.797 (7.211)	-3.613 (7.314)
Firm size	0.012 (0.077)	0.032 (0.075)	0.032 (0.069)	0.041 (0.067)	0.031 (0.067)	0.027 (0.067)	0.038 (0.064)
Firm capital intensity	-0.001* (0.000)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
Firm leverage	0.037 (0.470)	-0.437 (0.444)	-0.552 (0.417)	-0.597 (0.406)	-0.500 (0.413)	-0.540 (0.409)	-0.545 (0.389)
Firm performance	-0.002 (0.005)	-0.001 (0.008)	-0.005 (0.007)	-0.006 (0.008)	-0.005 (0.007)	-0.005 (0.007)	-0.007 (0.008)
Firm segments	-0.002 (0.012)	0.021 (0.013)	0.022† (0.011)	0.019† (0.011)	0.020† (0.011)	0.022* (0.011)	0.017 (0.011)
Firm IT segment share	0.179 (0.336)	0.592* (0.262)	0.550* (0.255)	0.537* (0.246)	0.517* (0.241)	0.541* (0.254)	0.482* (0.231)
CEO duality	0.085 (0.249)	0.051 (0.201)	0.017 (0.199)	0.012 (0.196)	-0.003 (0.202)	0.016 (0.197)	-0.013 (0.194)
TMT size	0.025† (0.015)	0.014 (0.017)	0.003 (0.019)	0.003 (0.019)	0.007 (0.018)	0.004 (0.018)	0.007 (0.018)
Independent director share	-0.449 (0.315)	-0.236 (0.382)	-0.244 (0.356)	-0.247 (0.367)	-0.232 (0.344)	-0.260 (0.346)	-0.258 (0.340)
Constant	0.260 (0.678)	-2.375** (0.816)	-2.156** (0.769)	-2.183** (0.814)	-2.254** (0.753)	-2.129** (0.731)	-2.262** (0.744)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,225	1,225	1,225	1,225	1,225	1,225	1,225
Chi^2		150.237	159.154	165.454	164.16	169.003	183.043
AIC		2082.67	2079.989	2080.953	2079.478	2081.107	2081.087
BIC		2317.77	2320.192	2326.267	2324.792	2326.42	2336.621

Note: All independent and control variables are lagged by one year. All continuous variables are winsorized at the 1% and 99% levels. Firm size is log-transformed. Firm-clustered robust standard errors in parentheses. † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.; *** $p < 0.001$

Regarding the moderating effect of *CEO IT background* when *IDI* is the dependent variable, we find that the interaction is negative and statistically significant in Model 3 in Table 6 but statistically insignificant when applying a 5%-threshold in the full model (H3a: β = -0.330, p = 0.048, 95% CI = [-0.657; -0.004] in Model 3, Table 6; β = -0.309, p = 0.065, 95% CI = [-0.637; 0.019] in Model 6, Table 6). When *CDI* is the dependent variable, the interaction term is statistically insignificant in the individual model but positive and statistically significant in the full model (H3b: β = 0.358, p = 0.144, 95% CI = [-0.122; 0.838] in Model 3, Table 7; β = 0.469, p = 0.045, 95% CI = [.009; 0.298] in Model 6, Table 7). However, when we assess the moderating role of *CEO role tenure*, our results do not provide a statistically significant interaction term when *IDI* is the dependent variable (H4a: see Table 6, Models 4 and 6). In contrast, we found that *CEO role tenure* negatively moderates the relationship between *CIO presence* and *CDI*, as the interaction term is negative and statistically significant (H4b: β = -0.065, p = 0.008, 95% CI = [-0.114; -0.017] in Model 4, Table 7; and β = -0.067, p = 0.006, 95% CI = [-0.115; -0.019] in Model 6, Table 7). Finally, our results show that *industry IT attention* positively moderates the relation between *CIO presence* and *IDI* (H5a: β = 17.383, p = 0.001, 95% CI = [6.700; 28.066] in Model 5, Table 6; β = 17.034, p = 0.002, 95% CI = [6.418; 27.651] in Model 6, Table 6). The effect of *industry IT attention* on the link between *CIO presence* and *CDI*, however, is statistically insignificant when applying a 5% threshold in the full model (H5b: β = 21.920, p = 0.127, 95% CI = [-6.244; 50.084] in Model 5, Table 7; and β = 25.743, p = 0.094, 95% CI = [-4.344; 55.830] in Model 6, Table 7). Overall, the full model results support H3b, H4b, and H5a.

Figure 2 presents the moderating effects for the five models with statistically significant and marginally significant interaction terms (H3a in Panel A, H3b in Panel B, H4b in Panel C, H5a in Panel D, H5b in Panel E). For the binary moderator *CEO IT background*, we chose 0 as the low and 1 as the high value. For the two continuous moderators, *CEO role tenure* and *industry IT attention*, we calculate a low value as one standard deviation below the mean and a high value as one standard deviation above the mean. The slopes for high moderator values are statistically significantly different from zero in Figure 2: Panel B (H3b; p = 0.05), Panel D (H5a; p < 0.01), and Panel E (H5b; p = 0.09). The slopes for low moderator values are statistically significantly different from zero in Figure 2: Panel A (H3a; p < 0.01) and Panel C (H4b; p = 0.06). All other slopes are not statistically significantly different from zero. Further tests for slope difference indicate that the two slopes for high and low moderator values in the interaction graphs are statistically significantly different in Figure 2: Panel B (H3b, p = 0.07), Panel C (H4b, p = 0.09), and Panel D (H5a, p < 0.01), but not in Panel A (H3a, p = 0.19) or Panel E (H5b, p = 0.15).

Endogeneity

It is difficult to determine whether it is the CIO promoting digital innovation or whether digitally innovative firms are simply more likely to install a CIO in their TMT. Beyond the theoretical arguments laid out in the first part of this study, we address concerns of reverse causality empirically in several other ways. First, in all regression models, we used lagged explanatory variables as well as time and industry fixed effects (Papies et al., 2017).

Second, we conducted instrumental variable regression analyses using fractional response probit models with endogenous regressors and maximum likelihood estimation. Instrumental variable estimation requires an instrument that correlates with the independent variable (*CIO presence*) but not with the unobserved determinants of the dependent variables (Angrist & Pischke, 2009). Following the methodology and line of argumentation in Germann et al. (2015), we determine *CIO industry prevalence* among peer firms and use it as an instrumental variable. We determine the relative prevalence of CIOs among the firms in the same industry on the two-digit NAICS level, excluding the focal firm. Since we assume that larger firms will have more visibility in their industry, we use the natural logarithm of a firm's assets as a weighting factor in this calculation. Germann et al. (2015) argue convincingly that a functional TMT member's prevalence in the industry is a good instrumental variable because it is a relevant predictor of that functional TMT member's presence in the focal firm (instrument relevance); however, it is not correlated with the error term that contains the omitted variables (exclusion restriction). We argue that both conditions also apply with regard to the CIO. To demonstrate the relevance of CIO industry prevalence, we follow Germann et al.'s (2015) argument that the presence of a functional TMT member correlates with the function's prevalence in the firm's industry: Firms in the same industry face comparable market conditions and are thus subject to the same external forces motivating the appointment of a CIO. Furthermore, we argue that CIO industry prevalence is also uncorrelated with omitted variables, thereby satisfying the exclusion restriction (Germann et al., 2015). For example, it is difficult for competitors to react strategically to firm-level omitted variables such as internal processes or organizational culture, which are hard to observe from the outside. Table A1 in the Appendix presents the results of these analyses. We observe a statistically significant but negative effect of the instrumental variable in the first stage in both models (p < 0.001). We find that the main relationship between *CIO presence* and both dependent variables remains statistically significant and positive (H1: p < 0.01 and H2: p < 0.01).

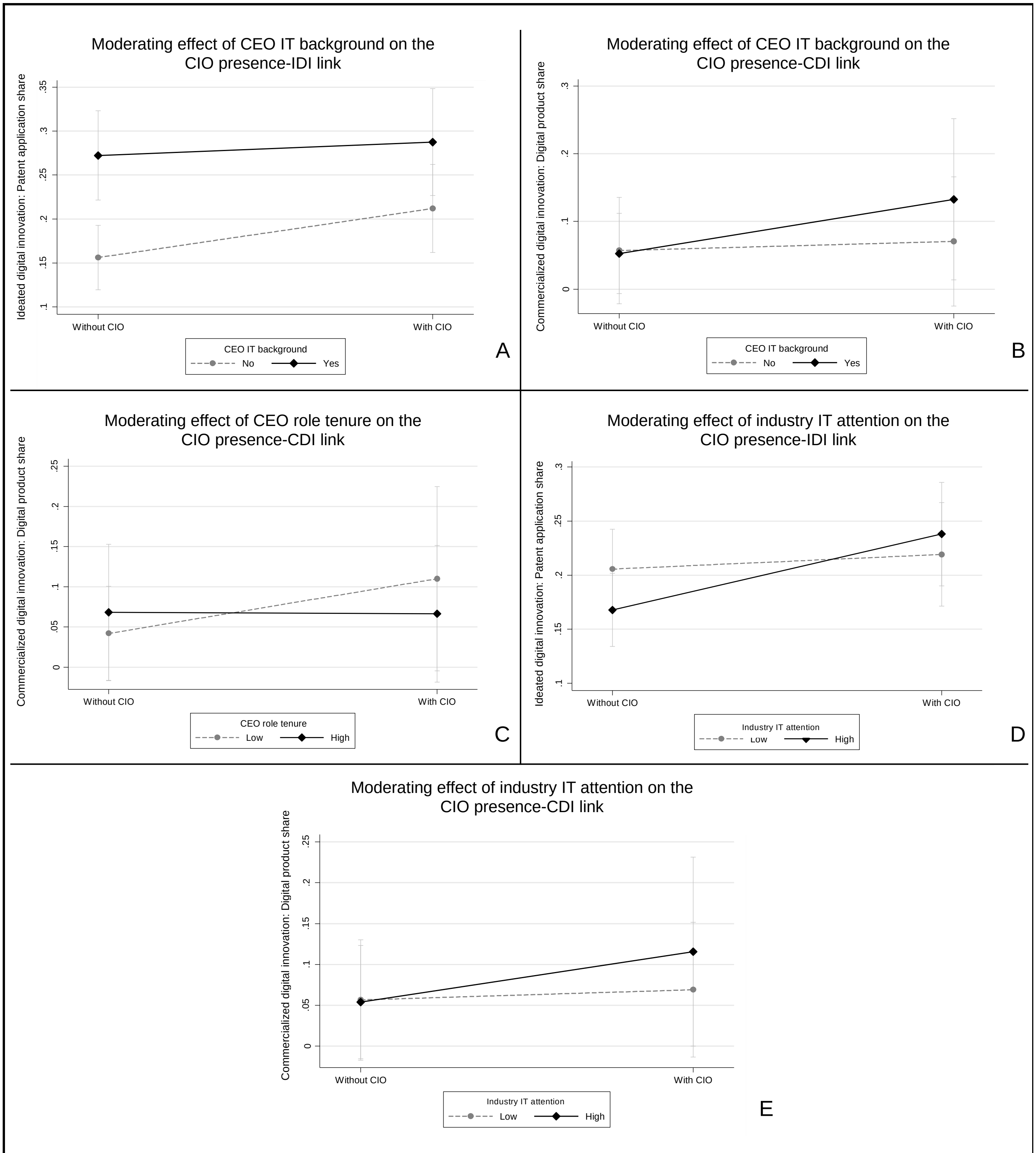

Figure 2. Moderating Effects of CEO IT Background, CEO Role Tenure, and Industry IT Attention

Table 8. Results of Propensity Score Matching

Outcome	Treated: *CIO present*	Untreated: *Control sample*	Absolute difference	Standard error	*T*-statistic	*p*
Ideated digital innovation	0.279	0.175	0.104	0.025	4.260	***
Commercialized digital innovation	0.059	0.030	0.029	0.011	2.720	**

Note: † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.; *** $p < 0.001$

Third, given the challenges of the instrumental variable approach (Rossi, 2014), we conducted propensity score matching to identify a control sample that closely matched our treatment sample on various firm-level characteristics. We selected the nearest neighbor without replacement in the same year and industry based on a propensity score estimated using a comprehensive set of matching criteria: all three moderators, the exclusion restriction, and the full set of controls used in our main model. The matching algorithm identified a suitable match for 418 out of 567 observations (73.7%) with CIO presence. In unreported results, the matched samples showed no statistically significant differences in each of the matching criteria at the 10% level, indicating that our matching approach identified comparable matches. When testing for differences in our dependent variables, we found that firms with a CIO in their TMT had significantly higher levels of *IDI* (H1; $p < 0.001$) and *CDI* (H2; $p = 0.007$), lending further support to the direct effects of *CIO presence* we hypothesized (see Table 8).

Fourth, our sample focuses on the years between 2008 and 2015. During this time, there were many new discoveries and disruptions in terms of how firms were using digital technologies to innovate and create value. We assume that any omitted variables in our models are therefore not time invariant, which is an identifying assumption underlying fixed-effects models. We concur with Germann et al. (2015, p. 10) that a fixed-effects model can be ruled out conceptually for this empirical issue. Lastly, we also tested for exogeneity using a simple Wald test, as well as Lochner and Moretti (2015) and Durbin-Wu-Hausman tests, and found that all three tests failed to reject exogeneity at the 5%-level. Based on these analyses, we conclude that our results are unlikely to have been biased by endogeneity.

Supplemental Analyses

In subsequent analyses, we found that our results hold in varying specifications. First, we tested whether the added complexity of a two-stage regression model confounded our results. We used a single-stage fractional regression model and removed firm years for which we could not identify any patent application or product announcement. We added *R&D stock intensity* as an additional control. The effect strength and significance of the results are consistent with our main results (see Table A2, Models 1 and 2 in the Appendix).

Second, research has recognized that patents differ significantly in terms of their relevance (Griliches et al., 1991). We employed an alternative measure of our first dependent variable: We determined *IDI* using non-self patent citation counts instead of patent application counts (see Table A2, Model 3 in the Appendix). The results remained stable. Third, we removed firms in industries that produce software or provide other IT-related services, following the classification by Rahmati et al. (2020) (see Table A2, Model 4 in the Appendix). Note that we only report results for the models estimating *IDI*, because our sample of product announcements does not include firms in IT software and service industries. Fourth, as an exclusion restriction for the generalized two-stage fractional regression models we used R&D intensity in the prior year, instead of R&D stock intensity, and removed firms with missing R&D expenditure instead of setting R&D expenditure to zero, as we did in our main models (see Table A2, Models 5 and 6 in the Appendix). In these models, the exclusion restriction is not consistently statistically significant, indicating that our main models provide more robust results. Nevertheless, we still found empirical evidence in support of our main results.

Since management attention is the core mechanism in our framework, we further assessed whether *CIO presence* has a positive impact on the way in which the top management team communicates about innovation and digital technology. We collected letters to shareholders for 2,300 firm years in our sample (80.6%) and conducted computer-aided text analysis (CATA) to calculate the share of words related to entrepreneurial orientation (capturing innovativeness and risk-taking) and digital orientation (measuring pursuit of digital technology-enabled opportunities). We employed the respective dictionaries proposed by Kindermann et al. (2021) and McKenny et al. (2018) to analyze the letters to shareholders. Using our standard set of controls and time and industry fixed effects with robust standard errors in single-stage fractional probit regression models, we found positive relationships between *CIO presence* in the prior year and entrepreneurial orientation ($\beta = 0.044$; $p = 0.035$) as well as digital orientation ($\beta = 0.068$; $p = 0.050$). These positive relationships support the argument that the presence of CIOs steers management attention toward innovation and digitalization.

Discussion

Main Findings

Examining how and under which conditions CIO presence in the TMT is related to firms' digital innovation outcomes, three main findings emerge from this study. First, we found strong support for our prediction that CIO presence enhances firms' IDI and CDI. Second, shedding new light on the CIO-CEO interplay we found that different CEO characteristics exert unique influences on the CIO-digital innovation relationship. CEO IT background amplifies the positive effect of CIO presence on CDI, whereas CEO role tenure attenuates this relationship. Third, while industry IT attention amplifies the positive relationship between CIO presence and IDI, our findings do not indicate such an effect for the relationship between CIO presence and CDI. Below, we discuss the implications of these findings.

Implications for IS Research and Practice

Our theorizing and findings contribute to IS research and practice in several meaningful ways. First, we add to the ongoing discussion about the role and impact of CIOs (e.g., Li et al., 2021). By showing that CIO presence in the TMT positively relates to a firm's digital innovation outcomes, we provide evidence for the claim that there is an increasing impact of the CIO on firm strategic activities (Liu & Preston, 2021). Despite the importance of the position for organizational outcomes such as firm performance and AI orientation (Li et al., 2021; Zafar et al., 2016), few studies have empirically explored the strategic dimension of the CIO's role. In this regard, we argue that our approach of focusing on CIOs at the TMT level is fruitful for teasing out the thus far neglected leadership role of CIOs. Given the complexity of most digital innovation projects involving cross-departmental collaboration, providing leadership for innovation is an essential part of the CIO job (Preston et al., 2008).

Distinguishing between ideation and commercialization with IDI and CDI, our findings underscore that by appointing a CIO to the TMT, firms can strengthen both the technological and market sides of their digital innovation strategy. This fine-grained analysis of different innovation outcomes constitutes an important contribution to IS research in its own right. In particular, the market side of digital innovation, which resembles Joshi et al.'s (2010) notion of commercialized innovation, is understudied in the literature (Karhade & Dong, 2021 for an exception). Revealing different patterns of relationships for IDI and CDI, our analysis of contingency factors indicates that there might be distinct mechanisms at play by which CIO presence influences these outcomes. This provides further support for the conceptual value of the ideated-commercialized distinction (Joshi et al., 2010). By operationalizing the two dimensions in novel ways (i.e., via patent application data and product announcements), we also respond to calls for methodological advancements in the study of digital innovation (Nambisan et al., 2017).

Second, we provide new insights into the contextual factors that influence CIOs' effectiveness in promoting digital innovation. We build on the principle of situated attention elaborated in the ABV (Brielmaier & Friesl, 2022) to argue and show that organizational structures and environmental contexts matter for the innovative work of CIOs. Focusing on the moderating roles of CEO and industry characteristics, our analyses paint a nuanced picture of how situational factors influence CIO-digital innovation linkages. We find that CEO characteristics as internal organizational factors influence the link between CIO presence and the market side of digital innovation, whereas environmental factors moderate the link between CIO presence and the technological side of digital innovation.

The observation that CEO characteristics act as contingency factors for the CIO-CDI relationship but not for the CIO-IDI relationship indicates that the discretion and power of CIOs vary depending on the type of innovation project at hand (i.e., patent vs. product innovation). While CIOs may be able to launch technology development projects that lead to patents relatively autonomously (see Benaroch & Chernobai, 2017), the same cannot be said about new product introductions that require cross-departmental collaboration and CEO support (e.g., Khilji et al., 2006). By showing that CEOs with an IT background can help CIOs promote the commercialization of digital innovations, whereas long-tenured CEOs impede them from doing so, we shed new light on the conditions under which CIOs can build on the support of CEOs. These findings extend research on the interplay between the CIO and CEO (Banker et al., 2011; Benlian & Haffke, 2016), thereby contributing to a more differentiated understanding of the role and influence of the CIO position.

This also applies to our findings on the contingent role of industry IT attention, which provide support for the idea that managerial attention is shaped by the industry context in which firms are embedded (Brielmaier & Friesl, 2022; Cho & Hambrick, 2006). In line with the concept of "industry-level attention" according to which industry participants have a shared focus of attention on a "limited set of issues, situations, and activities that represent potential problems or opportunities for the industry" (Hoffman & Ocasio, 2001, p. 415), our results show that a high level of industry IT attention strengthens the impact of CIOs on firms' IDI. However, one potential explanation for why no such moderation effect is found for the market side of digital innovation (i.e., CDI) lies in customer expectations and market requirements more generally, which firms need to consider when making product design decisions. Even when there is broad agreement among industry participants that IT investments need to grow, demand uncertainties and risk avoidance may prevent organizational decision makers from introducing products that are more digitally sophisticated than existing products on the market.

Finally, our study strengthens the ABV (Ocasio, 1997) as a theoretical lens to explain firm behavior in IS research. While the ABV has received considerable attention in fields such as strategy, marketing, and human resource management (e.g., Fu et al., 2019; Lee, 2021; Ocasio et al., 2018), IS research has used this theoretical perspective to a lesser extent. Drawing on some of Ocasio's (1997) core ideas, we elaborate the role of managerial attention as an underlying mechanism explaining the emergence of digital innovation. Highlighting the importance of two mechanisms, namely personal and structural attention, we not only explain how the CIO's own focus of attention influences the development and commercialization of digital technologies, but also theorize the CIO's context-dependent role in channeling and distributing the attention of other decision makers (e.g., fellow TMT members). Although not the focus of this study, our additional analyses of firm communication with shareholders provide initial evidence for the influence of CIOs on the latter mechanism of structural attention.

We argue that our attention-based theorizing has the potential to inform research on various topics in IS, including digital crowdfunding platforms (Luo et al., 2022), AI (Li et al., 2021), and digital business models (Bharadwaj et al., 2013). For example, research on digital crowdfunding platforms could be meaningfully extended by examining how such platforms can channel and distribute attention so that the matching between investors and entrepreneurs is facilitated or how the composition of a crowdfunding team affects its collective focus of attention. Similarly, AI research could benefit from adopting an ABV perspective. It would be particularly interesting to explore the role AI plays in structuring organizational problems and managerial attention. Finally, the ABV could contribute to a better understanding of the creation and implementation of digital business models by bringing new research questions into the foreground. For instance, in line with our theorizing on situated attention, it appears likely that the frequency or intensity with which competing firms reconfigure their business models affects focal firms' attention toward digital business model innovation.

Beyond these implications for research, our study has implications for practitioners who seek to enhance digital inventions and commercial applications in their firm. At a broad level, our findings suggest that appointing a CIO to the TMT helps firms to become digital innovators—a key success factor in today's competitive landscape (Nambisan et al., 2017). In particular, we show that CIO presence has a positive impact on both the technological and market side of digital innovation. We want to emphasize here that managerial attention is an important resource for digital innovation that firms need to manage carefully (e.g., Brielmaier & Friesl, 2022). Our research supports the idea that CIOs play a key role in shifting the attention of managers and employees at different hierarchical levels to digital technologies, acting as champions for digital innovation. Importantly, our moderation analyses reveal the conditions under which CIOs are more or less effective. While a CEO with an IT background is among the factors that make it easier for CIOs to promote digital innovation activities, a long role tenure of the CEO has the opposite effect. Being aware of these contingency factors can help firms make better decisions regarding the appointment of CIOs or how to support them effectively. For example, by reflecting on their own attention allocation, long-tenured CEOs can avoid the pitfall of unintentionally undermining the work of the CIO.

Limitations and Future Research

Our study has limitations that offer directions for further research. First, we introduce managerial attention as a key mechanism by which CIOs influence firms' digital innovation activities without explicitly developing and testing hypotheses about this mediating variable. However, the ABV and related research provide support for our theoretical expectations. In particular, consistent with our argument, studies show that the presence of chief marketing officers (Umashankar et al., 2022) or chief sustainability officers (Fu et al., 2019) shifts organizational attention to the respective issues. Our supplementary analyses provide initial insight into the mechanism at play by showing how CIOs influence the allocation of attention in firms to innovation and digital technologies in firms' letters to shareholders. There are likely further mechanisms (e.g., network effects) that may drive the relationships between CIO's presence and firms' digital innovation outcomes. Future research is needed to examine these mediating mechanisms. For example, studies could provide an in-depth qualitative analysis of how organizational attention processes are affected by the appointment of a CIO.

Second, although manufacturing firms constitute the largest part of most developed economies worldwide and have a strong focus on creating digital technologies and products, restricting our analyses regarding CDI to these firms limits the generalizability of our findings. For example, differences between manufacturing firms and those operating in other industries (e.g., software) need to be considered. In addition, we acknowledge that our patent-based measure of IDI does not perfectly capture intangible innovations that are typical for software and service industries. It also does not consider that firms in industries such as retail and wholesale typically only trade other firms' digital innovations instead of developing these innovations themselves. Studies in other contexts are therefore needed to replicate and extend our findings.

Third, further limitations of the measures used in this study need to be taken into account. To begin with, CIO presence in the TMT as our dichotomous independent variable is an imperfect measure of a CIO's actual actions and contributions. As discussed in the previous point on managerial attention as an underlying mechanism, future research delving into the behaviors of CIOs directed at digital innovation is warranted. Relatedly, our rather narrow definition of CIOs as TMT members may limit the generalizability of our findings. It is quite possible that CIOs who are not part of the TMT still significantly contribute to firms' digital innovation outcomes. While beyond the scope of this study, future work could examine whether the effects of CIOs vary depending on their hierarchical position or compare CIO effects with those of the related positions of chief digital officers and chief technology officers.

It should be also noted that our measure of industry IT attention reflects changes in the average IT investments within an industry rather than their absolute level. While increasing investments clearly indicate that an industry is currently paying attention to IT, future research is needed to examine the unique implications of industries' historically grown IT investment levels. Moreover, we recognize that our measure does not capture specific events such as the introduction of novel technological applications or innovative digital business models. Aggregate IT investment data might reflect these changes with a time delay or might not reflect them at all. Thus, we call for studies that investigate the impact of certain digitalization-related events on the CIO-digital innovation relationship.

Conclusion

This study explores the relationship between CIO presence in the TMT and firms' digital innovation activities. Based on the ABV, we suggest that managerial attention is a key mechanism through which CIOs can affect firms' resource allocation processes and innovation behavior. Our findings support our theoretical premise that CIO presence leads to both higher IDI and higher CDI. Furthermore, we find that CEO IT background, CEO role tenure, and industry IT attention are important boundary conditions that explain how CIO presence influences firms' digital innovation activities. Overall, this study contributes to a more nuanced picture of the impact of CIOs on digital innovation.

References

Ahn, Y. (2020). A socio-cognitive model of sustainability performance: Linking CEO career experience, social ties, and attention breadth. *Journal of Business Ethics*, *175*, 303-321. https://doi.org/10.1007/s10551-020-04651-w

Alcácer, J., & Gittelman, M. (2006). Patent citations as a measure of knowledge flows: The influence of examiner citations. *The Review of Economics and Statistics*, *88*(4), 774-779. https://doi.org/10.1162/rest.88.4.774.

Alcácer, J., Gittelman, M., & Sampat, B. (2009). Applicant and examiner citations in U.S. patents: An overview and analysis. *Research Policy*, *38*(2), 415-427. https://doi.org/10.1016/j.respol.2008.12.001

Angrist, J. D., & Pischke, J.-S. (2009). *Mostly harmless econometrics: An empiricist's companion*. Princeton University Press. https://doi.org/10.1257/jep.24.2.3

Arora, A., & Ceccagnoli, M. (2006). Patent protection, complementary assets, and firms' incentives for technology licensing. *Management Science*, *52*(2), 293-308. https://doi.org/10.1287/mnsc.1050.0437

Banker, R. D., Hu, N., Pavlou, P. A., & Luftman, J. (2011). CIO reporting structure, strategic positioning, and firm performance. *MIS Quarterly*, *35*(2), 487-504. https://doi.org/10.2307/23044053

Barker III, V. L., & Mueller, G. C. (2002). CEO characteristics and firm R&D spending. *Management Science*, *48*(6), 782-801. https://doi.org/10.1287/mnsc.48.6.782.187

Benaroch, M., & Chernobai, A. (2017). Operational IT failures, IT value destruction, and board-level IT governance changes. *MIS Quarterly*, *41*(3), 729-762.

Bendig, D., Wagner, R., Jung, C., & Nüesch, S. (2022). When and why technology leadership enters the C-suite: An antecedents perspective on CIO presence. *The Journal of Strategic Information Systems*, *31*(1), Article 101705. https://doi.org/10.1016/j.jsis.2022.101705

Benlian, A., & Haffke, I. (2016). Does mutuality matter? Examining the bilateral nature and effects of CEO-CIO mutual understanding. *The Journal of Strategic Information Systems*, *25*(2), 104-126. https://doi.org/10.1016/j.jsis.2016.01.001

Benner, M. J., & Tushman, M. (2015). Reflections on the 2013 Decade Award—"Exploitation, exploration, and process management: The productivity dilemma revisited" ten years later. *Academy of Management Review*, *40*(4), 497-514. https://doi.org/10.5465/amr.2015.0042

Blagoeva, R., Mom, T. J. M., Jansen, J. J. P., & George, G. (2020). Problem-solving or self-enhancement? A power perspective on how CEOs affect R&D search in the face of inconsistent feedback. *Academy of Management Journal*, *63*(2), 332-355. https://doi.org/10.5465/amj.2017.0999

Bloom, N., Sadun, R., & Van Reenen, J. (2012). Americans do IT better: US multinationals and the productivity miracle. *American Economic Review*, *102*(1), 167-201. https://doi.org/10.1257/aer.102.1.167

Branstetter, L. G., Drev, M., & Kwon, N. (2019). Get with the program: Software-driven innovation in traditional manufacturing. *Management Science*, *65*(2), 541-558. https://doi.org/10.1287/mnsc.2017.2960

Brielmaier, C., & Friesl, M. (2022). The attention-based view: Review and conceptual extension towards situated attention. *International Journal of Management Reviews*, *25*(1), 99-129. https://doi.org/10.1111/ijmr.12306

Burke, M. J., Finkelstein, L. M., & Dusig, M. S. (1999). On average deviation indices for estimating interrater agreement. *Organizational Research Methods*, *2*(1), 49-68. https://doi.org/10.1177/109442819921004

Burton Swanson, E., & Ramiller, N. C. (1997). The organizing vision in information systems innovation. *Organization Science*, *8*(5), 458-474. https://doi.org/10.1287/orsc.8.5.458

Cannella, A. A., Park, J.-H., & Lee, H.-U. (2008). Top management team functional background diversity and firm performance: Examining the roles of team member colocation and environmental uncertainty. *Academy of Management Journal*, *51*(4), 768-784. https://doi.org/10.5465/amr.2008.33665310

Carpenter, M. A., Geletkanycz, M. A., & Sanders, W. G. (2004). Upper echelons research revisited: Antecedents, elements, and consequences of top management team composition. *Journal of Management*, *30*(6), 749-778. https://doi.org/10.1016/j.jm.2004.06.001

Carpenter, M. A., & Wade, J. B. (2002). Microlevel opportunity structures as determinants of non-CEO executive pay. *Academy of Management Journal*, *45*(6), 1085-1103. https://doi.org/10.5465/3069426

Carter, M., Grover, V., & Thatcher, J. B. (2011). The emerging CIO role of business technology strategist. *MIS Quarterly Executive*, *10*(1), 19-29.

Chandy, R. K., & Tellis, G. J. (1998). Organizing for radical product innovation: The overlooked role of willingness to cannibalize. *Journal of Marketing Research*, *35*(4), 474-487. https://doi.org/10.1177/002224379803500406

Chandy, R. K., & Tellis, G. J. (2000). The incumbent's curse? Incumbency, size, and radical product innovation. *Journal of Marketing*, *64*(3), 1-17. https://doi.org/10.1509/jmkg.64.3.1.18033

Chen, D. Q., Zhang, Y., Xiao, J., & Xie, K. (2021). Making digital innovation happen: A chief information officer issue selling perspective. *Information Systems Research*, *32*(3), 987-1008. https://doi.org/10.1287/isre.2021.1008

Chen, Y.-C., & Wu, J.-H. (2011). IT management capability and its impact on the performance of a CIO. *Information & Management*, *48*(4), 145-156. https://doi.org/10.1016/ j.im.2011.04.001

Cho, T. S., & Hambrick, D. (2006). Attention as the mediator between top management team characteristics and strategic change: The case of airline deregulation. *Organization Science*, *17*(4), 453-469. https://doi.org/10.1287/orsc.1060.0192

Choi, I., Chung, S., Han, K., & Pinsonneault, A. (2021). CEO risk-taking incentives and IT innovation: The moderating role of a CEO's IT-related human capital. *MIS Quarterly*, *45*(4), 2175-2192. https://doi.org/10.25300/MISQ/2022/15606

Chun, M., & Mooney, J. (2009). CIO roles and responsibilities: Twenty-five years of evolution and change. *Information & Management*, *46*(6), 323-334. https://doi.org/10.1016/j.im.2009.05.005

Chung, S., Animesh, A., Han, K., & Pinsonneault, A. (2019). Software patents and firm value: A real options perspective on the role of innovation orientation and environmental uncertainty. *Information Systems Research*, *30*(3), 1073-1097. https://doi.org/10.1287/isre.2019.0854

Cohen, S. L., & Tripsas, M. (2018). Managing technological transitions by building bridges. *Academy of Management Journal*, *61*(6), 2319-2342. https://doi.org/10.5465/amj.2015.0690

Corwin, E. S., Loncarich, H., & Ridge, J. W. (2022). What's it like inside the hive? Managerial discretion drives TMT gender diversity of women-led firms. *Journal of Management*, *48*(4), 1003-1034. https://doi.org/10.1177/01492063211011755

Custódio, C., Ferreira, M. A., & Matos, P. (2019). Do general managerial skills spur innovation? *Management Science*, *65*(2), 459-476. https://doi.org/10.1287/mnsc.2017.2828

Cyert, R. M., & March, J. G. (1963). A behavioral theory of the firm. Prentice-Hall.

Darouichi, A., Kunisch, S., Menz, M., & Cannella Jr, A. A. (2021). CEO tenure: An integrative review and pathways for future research. *Corporate Governance: An International Review*, *29*(6), 661-683. https://doi.org/10.1111/corg.12396

Dewan, S., & Ramaprasad, J. (2014). Social media, traditional media, and music sales. *MIS Quarterly*, *38*(1), 101-122.

Dong, J. Q. (2021). Technological choices under uncertainty: Does organizational aspiration matter? *Strategic Management Journal*, *42*(5), 898-916. https://doi.org/10.1002/smj.3253

Eggers, J. P., & Kaplan, S. (2009). Cognition and renewal: Comparing CEO and organizational effects on incumbent adaptation to technical change. *Organization Science*, *20*(2), 461-477. https://doi.org/10.1287/orsc.1080.0401

Feng, C., Patel, P. C., & Fay, S. (2021). The value of the structural power of the chief information officer in enhancing forward-looking firm performance. *Journal of Management Information Systems*, *38*(3), 765-797. https://doi.org/10.1080/07421222.2021.1962599

Fernhaber, S. A., & Li, D. (2013). International exposure through network relationships: Implications for new venture internationalization. *Journal of Business Venturing*, *28*(2), 316-334. https://doi.org/10.1016/j.jbusvent.2012.05.002

Fichman, R. G., Dos Santos, B. L., & Zheng, Z. (2014). Digital innovation as a fundamental and powerful concept in the information systems curriculum. *MIS Quarterly*, *38*(2), 329-353.

Flammer, C., Hong, B., & Minor, D. (2019). Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: Effectiveness and implications for firm outcomes. *Strategic Management Journal*, *40*(7), 1097-1122. https://doi.org/10.1002/smj.3018

Fu, R., Tang, Y., & Chen, G. (2019). Chief sustainability officers and corporate social (ir)responsibility. *Strategic Management Journal*, *41*(4), 656-680. https://doi.org/10.1002/smj.3113

Gavetti, G., Greve, H. R., Levinthal, D. A., & Ocasio, W. (2012). The behavioral theory of the firm: Assessment and prospects. *Academy of Management Annals*, *6*(1), 1-40. https://doi.org/10.5465/19416520.2012.656841

Germann, F., Ebbes, P., & Grewal, R. (2015). The chief marketing officer matters! *Journal of Marketing*, *79*(3), 1-22. https://doi.org/10.1509/jm.14.0244

Gregory, R. W., Henfridsson, O., Kaganer, E., & Kyriakou, H. (2021). The role of artificial intelligence and data network effects for creating user value. *Academy of Management Review*, 46(3), 534-551. https://doi.org/10.5465/amr.2019.0178

Greve, H. R. (2008). A behavioral theory of firm growth: Sequential attention to size and performance goals. *Academy of Management Journal*, *51*(3), 476-494. https://doi.org/10.5465/amj.2008.32625975

Griliches, Z., Hall, B. H., & Pakes, A. (1991). R&D, patents, and market value revisited: Is there a second (technological opportunity) factor? *Economics of Innovation and New*

Technology, *1*(3), 183-201. https://doi.org/10.1080/1043859 9100000001

Gunz, H. P., & Jalland, R. M. (1996). Managerial careers and business strategies. *Academy of Management Review*, *21*(3), 718-756. https://doi.org/10.5465/AMR.1996.9702100313

Hall, B. H. (1990). *The manufacturing sector master file: 1959-1987*. National Bureau of Economic Research.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). *The NBER patent citation data file: Lessons, insights and methodological tools*. National Bureau of Economic Research.

Hambrick, D. C. (2007). Upper echelons theory: An update. *Academy of Management Review*, *32*(2), 334-343. https://doi.org/10.5465/ amr.2007.24345254

Hambrick, D. C., & Fukutomi, G. D. S. (1991). The seasons of a CEO's tenure. *Academy of Management Review*, *16*(4), 719-742. https://doi.org/10.5465/AMR.1991.4279621

Henderson, A. D., Miller, D., & Hambrick, D. C. (2006). How quickly do CEOs become obsolete? Industry dynamism, CEO tenure, and company performance. *Strategic Management Journal*, *27*(5), 447-460. https://doi.org/10.1002/smj.524

Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, *15*(2), 123-139.

Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization*, *28*(1), 52-61. https://doi.org/ 10.1016/j.infoandorg.2018.02.004

Hirshleifer, D., Low, A., & Teoh, S. H. (2012). Are overconfident CEOs better innovators? *The Journal of Finance*, *67*(4), 1457-1498. https://doi.org/10.1111/j.1540-6261.2012.01753.x

Hoffman, A. J., & Ocasio, W. (2001). Not all events are attended equally: Toward a middle-range theory of industry attention to external events. *Organization Science*, *12*(4), 414-434. https://doi.org/10.1287/orsc.12.4.414.10639

Joshi, K. D., Chi, L., Datta, A., & Han, S. (2010). Changing the competitive landscape: Continuous innovation through IT-enabled knowledge capabilities. *Information Systems Research*, *21*(3), 472-495. https://doi.org/10.1287/isre.1100.0298

Kahneman, D. (1973). *Attention and effort*. Prentice-Hall.

Kalnins, A. (2018). Multicollinearity: How common factors cause Type 1 errors in multivariate regression. *Strategic Management Journal*, *39*(8), 2362-2385. https://doi.org/10.1002/smj.2783

Karake, Z. A. (1995). The management of information technology, governance, and managerial characteristics. *Information Systems Journal*, *5*(4), 271-284. https://doi.org/10.1111/j.1365-2575. 1995.tb00099.x

Karhade, P., & Dong, J. Q. (2021). Information technology investment and commercialized innovation performance: Dynamic adjustment costs and curvilinear impacts. *MIS Quarterly*, *45*(3), 1007-1024.

Karimi, J., & Walter, Z. (2015). The role of dynamic capabilities in responding to digital disruption: A factor-based study of the newspaper industry. *Journal of Management Information Systems*, *32*(1), 39-81. https://doi.org/10.1080/07421222.2015. 1029380

Khilji, S. E., Mroczkowski, T., & Bernstein, B. (2006). From invention to innovation: Toward developing an integrated innovation model for Biotech firms. *Journal of Product Innovation Management*, *23*(6), 528-540. https://doi.org/ 10.1111/j.1540-5885.2006.00222.x

Kim, H. H., & Brynjolfsson, E. (2009). CEO compensation and information technology. In *Proceedings of the International Conference on Information Systems*.

Kindermann, B., Beutel, S., Garcia de Lomana, G., Strese, S., Bendig, D., & Brettel, M. (2021). Digital orientation: Conceptualization and operationalization of a new strategic orientation. *European Management Journal*, *39*(5), 645-657. https://doi.org/10.1016/j.emj.2020.10.009

Kohli, R., & Johnson, S. (2011). Digital transformation in latecomer industries: CIO and CEO leadership lessons from Encana Oil & Gas (USA) Inc. *MIS Quarterly Executive*, *10*(4), 141-156.

Kohli, R., & Melville, N. P. (2019). Digital innovation: A review and synthesis. *Information Systems Journal*, *29*(1), 200-223. https://doi.org/10.1111/isj.12193

Konchitchki, Y., & O'Leary, D. E. (2011). Event study methodologies in information systems research. *International Journal of Accounting Information Systems*, *12*(2), 99-115. https://doi.org/10.1016/j.accinf.2011.01.002

Kor, Y. Y., & Sundaramurthy, C. (2009). Experience-based human capital and social capital of outside directors. *Journal of Management*, *35*(4), 981-1006. https://doi.org/10.1177/014920 6308321551

Lee, S.-H. (2021). An attention-based view of strategic human resource management. *Academy of Management Perspectives*, *35*(2), 237-247. https://doi.org/10.5465/amp.2020.0099

Leidner, D. E., Preston, D., & Chen, D. (2010). An examination of the antecedents and consequences of organizational IT innovation in hospitals. *The Journal of Strategic Information Systems*, *19*(3), 154-170. https://doi.org/10.1016/j.jsis.2010.07.002

Li, J., Li, M., Wang, X., & Thatcher, J. B. (2021). Strategic directions for AI: The role of CIOs and boards of directors. *MIS Quarterly*, *45*(3), 1603-1644. https://doi.org/10.2533/MISQ/2021/16523

Liu, K., Li, J., Hesterly, W., & Cannella Jr, A. (2012). Top management team tenure and technological inventions at post-IPO biotechnology firms. *Journal of Business Research*, *65*(9), 1349-1356. https://doi.org/10.1016/j.jbusres.2011.09.024

Liu, X. K., & Preston, D. S. (2021). The Chief Information Officer: Impact on organizational forecasting outcomes. *Journal of the Association for Information Systems*, *22*(4), 7.

Lochner, L., & Moretti, E. (2015). Estimating and testing models with many treatment levels and limited instruments. *The Review of Economics and Statistics*, *97*(2), 387-397. https://doi.org/10.1162/REST_a_00475

Luo, X., Ling Ge, & Chong (Alex) Wang. (2022). Crowdfunding for microfinance institutions: The new hope? *MIS Quarterly*, *46*(1), 373-400. https://doi.org/10.25300/MISQ/2022/15406

Maclaurin, W. R. (1953). The sequence from invention to innovation and its relation to economic growth. *The Quarterly Journal of Economics*, *67*(1), 97-111. https://doi.org/10.2307/1884150

McKenny, A. F., Short, J. C., Ketchen, D. J., Payne, G. T., & Moss, T. W. (2018). Strategic entrepreneurial orientation: Configurations, performance, and the effects of industry and time. *Strategic Entrepreneurship Journal*, *12*(4), 504-521. https://doi.org/10.1002/sej.1291

Miller, D. (1991). Stale in the saddle: CEO tenure and the match between organization and environment. *Management Science*, *37*(1), 34-52. https://doi.org/10.1287/mnsc.37.1.34

Mitchell, V. L. (2006). Knowledge integration and information technology project performance. *MIS Quarterly*, *30*(4), 919-939. https://doi.org/10.2307/25148759

Mithas, S., Tafti, A., & Mitchell, W. (2013). How a firm's competitive environment and digital strategic posture influence digital business strategy. *MIS Quarterly*, *37*(2), 511-536.

Mudambi, R., & Swift, T. (2014). Knowing when to leap: Transitioning between exploitative and explorative R&D. *Strategic Management Journal*, *35*(1), 126-145. https://doi.org/10.1002/smj.2097

Nadkarni, S., & Barr, P. S. (2008). Environmental context, managerial cognition, and strategic action: An integrated view. *Strategic Management Journal*, *29*(13), 1395-1427. https://doi.org/10.1002/smj.717

Nambisan, S., Lyytinen, K., & Yoo, Y. (2020). *Handbook of digital innovation*. Edward Elgar.

Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy*, *48*(8), Article 103773. https://doi.org/10.1016/j.respol.2019.03.018

Nath, P., & Bharadwaj, N. (2020). Chief marketing officer presence and firm performance: Assessing conditions under which the presence of other C-level functional executives matters. *Journal of the Academy of Marketing Science*, *48*(4), 1-25.

Newman, D. A., & Sin, H.-P. (2020). Within-group agreement (r wg): Two theoretical parameters and their estimators. *Organizational Research Methods*, *23*(1), 30-64. https://doi.org/10.1177/1094428118809504

Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal*, *18*(S1), 187-206. https://doi.org/10.1002/(SICI)1097-0266(199707)18:1+<187::AID-SMJ936>3.0.CO;2-K

Ocasio, W., & Joseph, J. (2008). Rise and fall—or transformation? The evolution of strategic planning at the General Electric Company, 1940-2006. *Long Range Planning*, *41*(3), 248-272. https://doi.org/10.1016/j.lrp.2008.02.010

Ocasio, W., Laamanen, T., & Vaara, E. (2018). Communication and attention dynamics: An attention-based view of strategic change. *Strategic Management Journal*, *39*(1), 155-167. https://doi.org/10.1002/smj.2702

Papies, D., Ebbes, P., & Van Heerde, H. J. (2017). Addressing endogeneity in marketing models. In P. S. H. Leeflang, J. E. Wieringa, T. H. A. Bijmolt, & K. H. Pauwels (Eds.), *Advanced Methods for Modeling Markets* (pp. 581-627). Springer.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics*, *11*(6), 619-632. https://doi.org/10.1002/(SICI)1099-1255(199611)11:6<619::AID-JAE418>3.0.CO;2-1

Peppard, J. (2010). Unlocking the performance of the chief information officer (CIO). *California Management Review*, *52*(4), 73-99.

Peppard, J., Edwards, C., & Lambert, R. (2011). Clarifying the ambiguous role of the CIO. *MIS Quarterly Executive*, *10*(1), 31-44.

Preston, D. S., Chen, D., & Leidner, D. E. (2008). Examining the antecedents and consequences of CIO strategic decision-making authority: An empirical study. *Decision Sciences*, *39*(4), 605-642. https://doi.org/10.1111/j.1540-5915.2008.00206.x

Raes, A. M. L., Heijltjes, M. G., Glunk, U., & Roe, R. A. (2011). The interface of the top management team and middle managers: A process model. *Academy of Management Review*, *36*(1), 102-126. https://doi.org/10.5465/amr.2009.0088

Rahmati, P., Tafti, A., Westland, J., & Hidalgo, C. A. (2020). When all products are digital: Complexity and intangible value in the ecosystem of digitizing firms. *MIS Quarterly*, *45*(3), 1025-1058. https://doi.org/10.25300/MISQ/2021/15384

Ramalho, J. J. S., & da Silva, J. V. (2009). A two-part fractional regression model for the financial leverage decisions of micro, small, medium and large firms. *Quantitative Finance*, *9*(5), 621-636. https://doi.org/10.1080/14697680802448777

Ramasubbu, N., & Bardhan, I. (2021). Reconfiguring for agility: Examining the performance implications of project team autonomy through an organizational policy experiment. *MIS Quarterly*, *45*(4), 2261-2280.

Ren, C. R., & Guo, C. (2011). Middle managers' strategic role in the corporate entrepreneurial process: Attention-based effects. *Journal of Management*, *37*(6), 1586-1610. https://doi.org/10.1177/0149206310397769

Robertson, T. S., Eliashberg, J., & Rymon, T. (1995). New product announcement signals and incumbent reactions. *Journal of Marketing*, *59*(3), 1-15. https://doi.org/10.1177/002224299505900301

Roodman, D. (2011). Fitting fully observed recursive mixed-process models with CMP. *The Stata Journal*, *11*(2), 159-206. https://doi.org/10.1177/1536867X1101100202

Rossi, P. E. (2014). Even the rich can make themselves poor: A critical examination of IV methods in marketing applications. *Marketing Science*, *33*(5), 655-672. https://doi.org/10.1287/mksc.2014.0860

Rubera, G., & Kirca, A. H. (2012). Firm innovativeness and its performance outcomes: A meta-analytic review and theoretical integration. *Journal of Marketing*, *76*(3), 130-147. https://doi.org/10.1509/jm.10.0494

Rudolph, C. W., Kooij, D. T. A., Rauvola, R. S., & Zacher, H. (2018). Occupational future time perspective: A meta-analysis of antecedents and outcomes. *Journal of Organizational Behavior*, *39*(2), 229-248. https://doi.org/10.1002/job.2264

Savage, J. P., Li, M., Turner, S. F., Hatfield, D. E., & Cardinal, L. B. (2020). Mapping patent usage in management research: The state of prior art. *Journal of Management*, *46*(6), 1121-1155. https://doi.org/10.1177/0149206320916233

Schwiebert, J., & Wagner, J. (2015). A generalized two-part model for fractional response variables with excess zeros. *Proceedings of the Jahrestagung des Vereins für Socialpolitik*. Available at https://www.econstor.eu/handle/10419/113059

Simon, H. A. (1947). *Administrative behavior: A study of decision-making process in administrative organization*. Macmillan.

Singh, A., & Hess, T. (2017). How chief digital officers promote the digital transformation of their companies. *MIS Quarterly Executive*, *16*(1), 1-17.

Smaltz, D. H., Sambamurthy, V., & Agarwal, R. (2006). The antecedents of CIO role effectiveness in organizations: An empirical study in the healthcare sector. *IEEE Transactions on Engineering Management*, *53*(2), 207-222. https://doi.org/10.1109/TEM.2006.872248

Somaya, D. (2012). Patent strategy and management: An integrative review and research agenda. *Journal of Management*, *38*(4), 1084-1114. https://doi.org/10.1177/0149206312444447

Sorescu, A., Shankar, V., & Kushwaha, T. (2007). New product preannouncements and shareholder value: Don't make promises you can't keep. *Journal of Marketing Research*, *44*(3), 468-489. https://doi.org/10.1509/jmkr.44.3.468

Sunder, J., Sunder, S. V., & Zhang, J. (2017). Pilot CEOs and corporate innovation. *Journal of Financial Economics*, *123*(1), 209-224. https://doi.org/10.1016/j.jfineco.2016.11.002

Surroca, J., Prior, D., & Tribó Giné, J. A. (2016). Using panel data dea to measure CEOs' focus of attention: An application to the study of cognitive group membership and performance. *Strategic Management Journal*, *37*(2), 370-388. https://doi.org/10.1002/smj.2350

Tuggle, C. S., Schnatterly, K., & Johnson, R. A. (2010). Attention patterns in the boardroom: How board composition and processes affect discussion of entrepreneurial issues. *Academy of Management Journal*, *53*(3), 550-571. https://doi.org/10.5465/amj.2010.51468687

Turedi, S. (2020). The interactive effect of board monitoring and Chief Information Officer presence on information technology investment. *Information Systems Management*, *37*(2), 113-123. https://doi.org/10.1080/10580530.2019.1696589

Umashankar, N., Bahadir, S. C., & Bharadwaj, S. (2022). Despite efficiencies, mergers and acquisitions reduce firm value by hurting customer satisfaction. *Journal of Marketing*, *86*(2), 66-86. https://doi.org/10.1177/00222429211024255

U.S. Bureau of Economic Analysis. (2022). *Detailed data for fixed assets and consumer durable goods*. https://apps.bea.gov/

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems*, *28*(2), 118-144. https://doi.org/10.1016/j.jsis.2019.01.003

Villadsen, A. R., & Wulff, J. N. (2021). Are you 110% sure? Modeling of fractions and proportions in strategy and management research. *Strategic Organization*, *19*(2), 312-337. https://doi.org/10.1177/1476127019854966

Weill, P., & Woerner, S. L. (2013). The future of the CIO in a digital economy. *MIS Quarterly Executive*, *12*(2), 65-75.

Wu, S., Levitas, E., & Priem, R. L. (2005). CEO tenure and company invention under differing levels of technological dynamism. *Academy of Management Journal*, *48*(5), 859-873. https://doi.org/10.5465/amj.2005.18803927

Wulff, J. N. (2019). Generalized two-part fractional regression with cmp. *The Stata Journal*, *19*(2), 375-389. https://doi.org/10.1177/1536867X19854017

Yoo, Y., Boland Jr, R. J., Lyytinen, K., & Majchrzak, A. (2012). Organizing for innovation in the digitized world. *Organization Science*, *23*(5), 1398-1408. https://doi.org/10.1287/orsc.1120.0771

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research Commentary—The new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, *21*(4), 724-735. https://doi.org/10.1287/isre.1100.0322

Zafar, H., Ko, M. S., & Osei-Bryson, K.-M. (2016). The value of the CIO in the top management team on performance in the case of information security breaches. *Information Systems Frontiers*, *18*(6), 1205-1215. https://doi.org/10.1007/s10796-015-9562-5

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Appendix

Table A1. Results of Fractional Response Model with Endogenous Regressors Using CIO Prevalence as an Instrumental Variable

Variables	Model 1: *IDI*	Model 2: *CDI*
CIO presence	1.100 (0.422) **	1.316 (0.435) **
CEO IT background	0.489 (0.104) ***	0.113 (0.131)
CEO role tenure	0.004 (0.006)	0.024 (0.010) *
Industry IT attention	-3.518 (2.846)	-4.122 (7.295)
Firm size	0.190 (0.051) ***	0.033 (0.064)
Firm capital intensity	0.000 (0.000)	-0.001 (0.001)
Firm leverage	-0.883 (0.336) **	-0.618 (0.398)
Firm performance	0.001 (0.005)	-0.008 (0.006)
Firm segments	-0.001 (0.008)	0.021 (0.009) *
Firm IT segment share	1.204 (0.207) ***	0.461 (0.200) *
CEO duality	-0.175 (0.183)	0.061 (0.165)
TMT size	-0.044 (0.016) **	-0.019 (0.020)
Independent director share	-0.121 (0.314)	-0.369 (0.257)
Constant	-3.483 (0.569) ***	-2.022 (0.660) **
First stage: CIO industry prevalence	-1.247 (0.201) ***	-5.523 (0.673) ***
Industry fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
N	2,852	1,225
Chi²	637.605	102.456
AIC	4,400.64	1369.924
BIC	4,853.28	1615.238

Note: Controls in the first stage are included but not reported here. Both the first and second stages include industry- and year-fixed effects. All independent and control variables are lagged by one year. All continuous variables are winsorized at the 1% and 99% levels. Firm size is log-transformed. Firm-clustered robust standard errors in parentheses. † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.; *** $p < 0.001$

Table A2. Robustness Checks

Variables	Single-stage fractional probit regression, removing firm years without any patent application or product announcement		GTP-FRM: Alternative operationalization of the dependent variable	GTP-FRM: Removing IT software and service industries	GTP-FRM: Using R&D intensity as an exclusion restriction	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent variable	*IDI*	*CDI*	*Patent citations*	*IDI*	*IDI*	*CDI*
CIO presence	0.360 ** (0.146)	0.555 * (0.226)	0.310 * (0.152)	0.352 * (0.148)	0.351 * (0.144)	0.553 * (0.228)
CIO presence × CEO IT background	-0.292 † (0.166)	0.468 * (0.234)	-0.444 ** (0.161)	-0.420 * (0.167)	-0.302 (0.169)	0.470 * (0.234)
CIO presence × CEO role tenure	0.005 (0.016)	-0.067 ** (0.025)	0.002 (0.017)	0.007 (0.016)	0.006 (0.016)	-0.067 ** (0.025)
CIO presence × Industry IT attention	17.379 *** (5.467)	25.802 † (15.384)	14.092 * (5.556)	16.257 ** (6.261)	17.489 ** (5.464)	25.648 (15.323)
Firm R&D stock intensity	0.568 (0.590)	-0.165 (0.636)				
CEO IT background	0.434 *** (0.102)	-0.105 (0.134)	0.418 *** (0.108)	0.419 *** (0.125)	0.451 *** (0.105)	-0.105 (0.131)
CEO role tenure	0.004 (0.008)	0.033 ** (0.010)	0.001 (0.008)	0.006 (0.010)	0.005 (0.008)	0.032 ** (0.010)
Industry IT attention	-10.234 *** (3.028)	-3.714 (7.015)	-7.152 * (3.329)	-10.917 ** (3.542)	-10.368 *** (3.018)	-3.308 (7.103)
Firm size	0.043 (0.052)	0.038 (0.064)	0.036 (0.056)	0.007 (0.077)	0.035 (0.052)	0.040 (0.064)
Firm capital intensity	0.000 (0.000)	-0.001 (0.001)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.001 (0.001)
Firm leverage	-1.173 *** (0.309)	-0.558 (0.393)	-0.897 ** (0.294)	-1.122 *** (0.328)	-1.211 *** (0.311)	-0.547 (0.397)
Firm performance	0.005 (0.003)	-0.007 (0.008)	0.005 (0.005)	0.002 (0.003)	0.005 (0.003)	-0.007 (0.008)
Firm segments	-0.008 (0.008)	0.016 (0.010)	-0.011 (0.008)	-0.012 (0.009)	-0.010 (0.008)	0.016 (0.010)
Firm IT segment share	1.038 *** (0.192)	0.475 * (0.227)	0.989 *** (0.188)	1.241 *** (0.308)	1.057 *** (0.187)	0.485 * (0.222)
CEO duality	-0.145 (0.174)	-0.013 (0.191)	-0.229 (0.162)	-0.161 (0.181)	-0.168 (0.172)	-0.011 (0.192)
TMT size	-0.011 (0.010)	0.007 (0.015)	-0.007 (0.010)	-0.010 (0.011)	-0.011 (0.010)	0.008 (0.015)
Independent director	-0.074 (0.373)	-0.258 (0.312)	-0.131 (0.280)	-0.076 (0.407)	-0.088 (0.368)	-0.285 (0.303)
Constant share	-1.984 *** (0.572)	-2.259 *** (0.611)	-1.562 * (0.649)	-1.540 (0.896)	-1.801 ** (0.573)	-2.303 *** (0.636)
First stage: R&D stock intensity			50.148 * (24.444)	90.872 *** (27.402)		
First stage: R&D intensity					32.304 ** (11.353)	1.371 (0.976)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	*2,002*	*774*	*2,852*	*2,703*	*2,038*	*1,169*
Chi^2	803.66	119.62	946.584	1,063.53	45,401.94	179.283
AIC	1,572.88	519.12	3,596.50	3,297.20	1,748.37	1,936.93
BIC	1,802.56	644.71	4,061.05	3,757.57	2,113.65	2,190.12

Note: GTP-FRM: Generalized two-stage fractional regression model. Controls in first stage are included but not reported here. Both first and second stage include industry- and year-fixed effects. All independent and control variables are lagged by one year. All continuous variables are winsorized at the 1% and 99% levels. Firm size is log-transformed. Firm-clustered robust standard errors in parentheses.
† $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.; *** $p < 0.001$