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REVIEW ARTICLE

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Strategic leadership and technological innovation: A comprehensive review and research agenda

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Abstract

Research Question/Issue: We review the literature on the relationship between strategic leadership and technological innovation.

Research Findings/Insights: We identify the theoretical lenses that researchers apply when studying strategic leadership and innovation, most notably agency theory and upper echelons theory. We review the innovation constructs and measures that scholars employ, and we survey the links among strategic leaders' characteristics and technological innovation. Ultimately, we organize the literature into an integrative framework that provides a concise overview of the extant knowledge, and we outline an agenda for future research.

Theoretical/Academic Implications: First, we offer scholars a discipline-spanning overview of the extant knowledge on the topic. Second, by integrating important aspects of corporate governance, such as the role of the board of directors, incentives for the chief executive officer or the top management team, and firm ownership, into the context of technological innovation, we highlight the vital role it plays in the realm of technological innovation. Third, we provide a useful guide for scholars and direct their work towards fruitful avenues for future research.

Practitioner/Policy Implications: We offer insights for practitioners interested in better understanding the bidirectional relationship between strategic leadership and technological innovation. In particular, our framework and our detailed analysis of the impact of strategic leaders on technological innovation can guide shareholders and board members in matters related to board composition as well as top executive selection and compensation.

KEYWORDS

Corporate governance, innovation, strategic leadership, technology

1 | INTRODUCTION

Scholars have long sought to understand technological innovation (Ahuja, Lampert, & Tandon, 2008; Dosi, 1982; Schumpeter, 1942; Teece, 1996), which can be broadly defined as changes in the ways value is created and captured in a given field (Damanpour, 1987; Hill & Rothaermel, 2003). Such changes include both discontinuous technological breakthroughs and incremental progress (Anderson & Tushman, 1990; Dewar & Dutton, 1986). Technological innovation is vital for the survival of companies because, without it, firms are unlikely to generate a sustainable competitive advantage (Hill & Rothaermel, 2003; Tripsas & Gavetti, 2000). The ability to adopt technologies is particularly important considering today's rapid technical advances, which in turn trigger grand challenges and opportunities (Tidd & Bessant, 2018).

Not surprisingly, given the key role of technological innovation, researchers have increasingly focused on the impact of strategic leaders—those executives who, as members of the board of directors or the top management team (TMT), are particularly influential (Finkelstein, Hambrick, & Cannella, 2009). Upper echelons theory suggests that strategic leaders affect organizational outcomes in general and innovation in particular (Hambrick & Mason, 1984), especially because they influence organizational attention, resource commitment, strategic choices, and implementation strategies (Carpenter, Geletkanycz, & Sanders, 2004; Gerstner, König, Enders, & Hambrick, 2013; Kaplan, 2008a). In this vein, researchers in various disciplines, including corporate governance (e.g., Rose, Rose, Norman, & Mazza, 2014), strategic management (e.g., Kor, 2006), finance (e.g., Ammann, Horsch, & Oesch, 2016), and entrepreneurship (e.g., Gedajlovic, Cao, & Zhang, 2012), have studied the relationship between strategic leaders and innovation, creating a need to consolidate the current state of knowledge.

Scholars have conducted valuable reviews in the field of innovation, including reviews of literature on the role of leadership. However, the limited reach of these reviews has ramifications for the analytic, predictive, and normative potential of research in this domain. Three limitations are particularly noteworthy. First, several broad reviews of the innovation literature identify managerial characteristics as one of several antecedents of technological innovation (Ahuja, Lampert, & Tandon, 2008) or technological discontinuities (Eggers & Park, 2018), but they hardly discuss the paths of influence. Second, some reviews offer outdated and incomplete overviews of the relevant characteristics of strategic leaders. For example, Crossan and Apaydin (2010) investigated the impact of the board and the TMT on innovation. However, that review is a decade old and only captures a small subset of the relevant characteristics of strategic leaders. Third, some reviews only link certain strategic leaders with specific innovation outcomes. For example, Back and Bausch (2019) examined the impact of chief executive officer (CEO) leadership on various firm-level antecedents of product innovation, such as social capital. Yet they do not consider a substantial number of studies that directly link CEO characteristics to technological innovation more broadly, and they do not consider strategic leaders other than the CEO. As such, no comprehensive review on strategic leadership and technological innovation is available, making it difficult for scholars to build on previous findings and identify relevant research questions.

Our review fills this gap. We aim to answer four interrelated questions: (1) What are the main theoretical lenses that scholars have applied when exploring the relationship between strategic leadership and technological innovation? (2) Which constructs and measures of technological innovation have scholars combined with certain facets of strategic leadership? (3) How are the characteristics of strategic leaders empirically related to different aspects of innovation? and (4) What are potentially fruitful avenues for future research?

2 | METHOD

To ensure a comprehensive account of the literature, we conducted a systematic review (e.g., David & Han, 2004; Rousseau, Manning, & Denyer, 2008). Given the multidisciplinary nature of the domain, we first identified 35 relevant peer-reviewed journals from different fields. These included the 30 outlets used in Wowak et al.'s (2017) recent review of incentives in strategic leadership. To specifically capture corporate-governance aspects, we also included a leading journal focused on that topic. In addition, owing to the focus of this review, we included two journals concerned with innovation, which two innovation scholars confirmed were the most important in the field. Finally, we included two major journals dealing with family firms, as family firms are one of the most prevalent firm types (La Porta, Lopez-De-Silanes, & Shleifer, 1999; Lodh, Nandy, & Chen, 2014). Moreover, family ownership and family involvement in strategic decision making substantially affect firms' technological innovation (De Massis, Frattini, & Lichtenthaler, 2013; Lodh, Nandy, & Chen, 2014). In fact, as De Massis et al. (2013, p. 10) noted, "there are strong theoretical reasons to believe that the antecedents and effects of technological innovation are different in family and nonfamily firms." Again, we validated our selection with two family business scholars. Table 1 provides an overview of the journals included in our review.

Using the above-mentioned definitions of strategic leadership and technological innovation as our conceptual anchors, we created a list of keywords. To validate our selection of keywords, we discussed them with management and innovation scholars and consulted scholars from economics and finance. These discussions led to the addition of a few keywords to our initial list. Table 2 shows the final list of keywords used in our literature search.

We set the review's starting point to 1984 to cover all literature published after Hambrick and Mason's (1984) seminal paper, which highlighted the importance of strategic leaders for organizational outcomes and laid the foundations for upper echelons theory. We then identified an initial sample of 937 articles published before the end of 2019 using the *Web of Science* database.

We read all articles' abstracts and, if necessary, their main texts and retained those articles that fulfilled two criteria. First, each article had to examine strategic leaders (i.e., boards of directors, CEOs, other TMT members, and/or business unit heads) (Finkelstein, Hambrick, & Cannella, 2009). Second, each article had to focus on *technological* innovation (Damanpour, 1987). We removed articles in which the hypotheses or propositions were not related to both criteria. Moreover, we removed articles dealing with young firms and start-ups owing to the specific context in which these firms and their strategic leaders operate (e.g., Park & Tzabbar, 2016).

Overall, we retained 158 articles and systematically coded each article for central theoretical and methodological aspects. For example, we examined the theoretical lens(es) that each study applied as well as the methodological approaches and the results. Table A1 in Data S1 summarizes the studies we reviewed.

In line with the growing importance of technological innovation for organizations (Tidd & Bessant, 2018), the number of studies on

TABLE 1 Selected journals

Journals
Academy of Management Journal[a]
Academy of Management Review[a]
Accounting, Organizations and Society[a]
Accounting Review[a]
Administrative Science Quarterly[a]
American Economic Review[a]
Contemporary Accounting Research[a]
Corporate Governance: An International Review[b]
Entrepreneurship Theory and Practice[a]
Family Business Review[b]
Human Resource Management[a]
Journal of Accounting and Economics[a]
Journal of Accounting Research[a]
Journal of Applied Psychology[a]
Journal of Business Venturing[a]
Journal of Family Business Strategy[b]
Journal of Finance[a]
Journal of Financial Economics[a]
Journal of Financial and Quantitative Analysis[a]
Journal of International Business Studies[a]
Journal of Management[a]
Journal of Management Studies[a]
Journal of Organizational Behavior[a]
Journal of Political Economy[a]
Journal of Product Innovation Management[b]
Leadership Quarterly[a]
Management Science[a]
Organization Science[a]
Personnel Psychology[a]
Quarterly Journal of Economics[a]
Research Policy[b]
Review of Economic Studies[a]
Review of Financial Studies[a]
Strategic Management Journal[a]
Strategic Organization[a]

[a]Journals used by Wowak et al. (2017).
[b]Additional journals.

TABLE 2 Keywords

Keywords strategic leadership
Strategic leader(s/ship)
Upper echelon(s)
Board(s)
Director(s)
Officer(s)
Top management
TMT(s)
Executive(s)
Top manager(s)
Business (unit) head(s)
Business (unit) leader(s)
VP/SVP/vice president
CEO(s)
CFO(s)
CMO(s)
CTO(s)
COO(s)
CSO(s)
CIO(s)
CDO(s)
Keywords technological innovation
Ambidex*
Discontinuous technology
Disruptive technology
Exploitation
Exploration
Innovat*
Invent*
New process
New product
New service
Quality ladders
Research & (and) development/R&D
Schumpeterian growth
Technological change/novelty/search
Technology

Note. We use asterisks (*) at the end of a keyword to account for variations in this root word (e.g., our results include all words containing the root 'innovat', such as innovation, innovator, or innovative).

strategic leadership and technological innovation rose over time. As Figure 1 shows, only one-third of the identified studies were published between 1984 and 2009, although the number of articles grew substantially in the last decade.

An analysis of the studies' research approaches and geographical focus reveals other interesting insights, which are summarized in Table 3. First, most studies employed a quantitative research approach, usually based on archival data or, to a lesser extent, surveys. Few studies used qualitative research methods, such as case studies, or employed experimental or conceptual approaches. In addition, many of the empirical studies focused on the United States, followed by a focus on multicountry datasets. Little research investigated individual countries other than the United States, with China being a distant second.

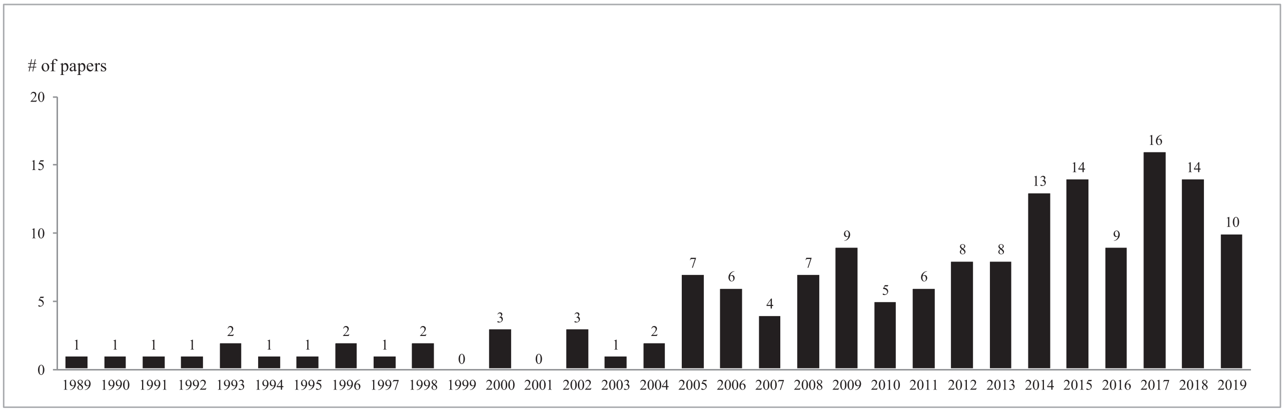

FIGURE 1 Articles included in review by year of publication

TABLE 3 Description of sample

Characteristics	No. of papers	Percentage of sample
Type	158	100
Quantitative: mostly archival data	83	53
Quantitative: mostly survey data	60	38
Qualitative	4	2
Conceptual	6	4
Meta-analysis	4	2
Experimental	1	1
Geographical scope	158	100
United States	83	53
Multicountry	27	17
China	12	8
Other single country	30	19
n/a	6	4

3 | AN INTEGRATIVE FRAMEWORK ON STRATEGIC LEADERS AND TECHNOLOGICAL INNOVATION

A framework that aggregates the findings from our analysis is shown in Figure 2. We employ a strategic leadership perspective, which assumes that strategic leaders' cognitive bases and values affect innovation through a filtering process (Finkelstein, Hambrick, & Cannella, 2009; Hambrick & Mason, 1984). By extension, we acknowledge that firm leaders may be affected by firm characteristics, and we also consider such relationships.

Our framework displays the main *theoretical lenses* used by scholars. Moreover, it includes the key individual-level and group-level characteristics of *strategic leaders* engaged with technological innovation. We distinguish between board and TMT characteristics, and we split the constructs into those focused on these groups as a whole and those focused on individual members of the board or TMT. Owing to the prominent role of the CEO in organizations (Finkelstein, Hambrick, & Cannella, 2009), we review CEO characteristics separately. We link strategic leaders' characteristics to the major innovation-related constructs. First, we consider *innovation input*, such as research and development (R&D) intensity (e.g., Cremers, Litov, & Sepe, 2017). Second, we consider *innovation output*, such as patents (e.g., Custódio, Ferreira, & Matos, 2019). Third, given the challenges of transforming innovation input into output (Duran, Kammerlander, van Essen, & Zellweger, 2016), we consider the relationship between strategic leaders' characteristics and the *innovation process*, such as product development (e.g., Swink, 2000). Fourth, we look at strategic leadership and aspects of the *intraorganizational innovation context*, such as a firm's innovation orientation (e.g., Carmeli & Halevi, 2009). Finally, our framework depicts the consequences of the relationship between strategic leadership and technological innovation for firm *performance* and describes moderating *environmental* and *organizational factors*. All in all, we strive to provide a concise overview of the extant knowledge and to highlight gaps in that knowledge.

3.1 | Main theoretical lenses

Figure 3 summarizes our findings regarding the main theoretical lenses. Upper echelons theory (Hambrick & Mason, 1984) is the most widely used theory (37 articles). Most scholars using this theory examine the impact of CEO and group-level TMT characteristics on innovation (e.g., Barker & Mueller, 2002; Talke, Salomo, & Kock, 2011). Few studies focus on the board or individual TMT members other than the CEO (Garms & Engelen, 2019; Kor, 2006; Shi, Pathak, Song, & Hoskisson, 2018). This is not surprising given the initial emphasis of upper echelons theory on CEO and group-level TMT characteristics (Carpenter, Geletkanycz, & Sanders, 2004). Several studies supplement upper echelons theory with other theories, such as leadership theories or personality theory. For instance, Makri and Scandura (2010) found that the interaction between the CEO's

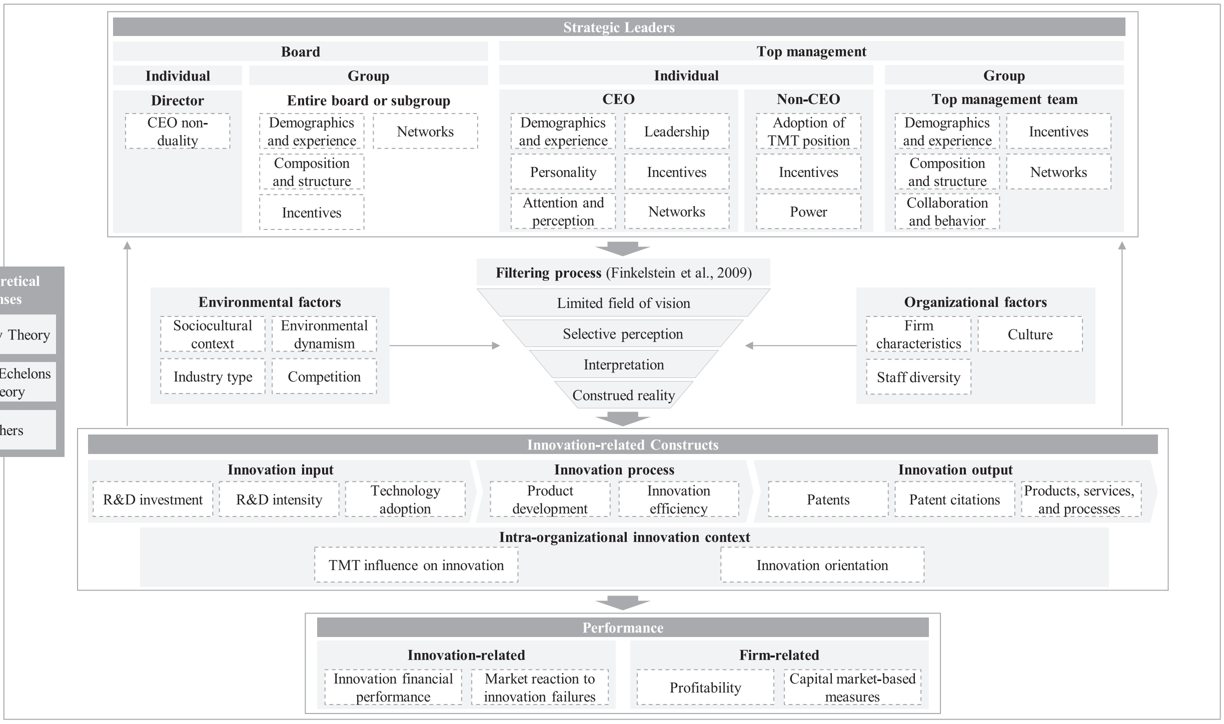

FIGURE 2 An integrative framework on strategic leaders and technological innovation. CEO, chief executive officer; R&D, research and development

creative leadership and operational leadership is positively related to a firm's innovation quantity. Moreover, Gerstner et al. (2013) showed that narcissistic CEOs are more willing to adopt discontinuous technologies.

Agency theory (Jensen & Meckling, 1976) is the second most frequently used theory (31 articles). In line with agency theory's focus on the relationship between principles and agents (Eisenhardt, 1989), several studies shed light on the role of board-level characteristics in interaction with CEO (e.g., Lim, 2015) or TMT characteristics (e.g., Kang & Zaheer, 2018; Kor, 2006). For example, Zona (2016) analyzed the interactive effect of the board's outsider ratio and CEO tenure on R&D intensity. Other articles focus on relationships between innovation and certain board characteristics, such as board composition (e.g., Osma, 2008; Robeson & O'Connor, 2013), or board compensation and ownership (e.g., Deutsch, 2007; Kang & Zaheer, 2018). Some studies investigate individual CEO characteristics (e.g., Balkin, Markman, & Gomez-Mejia, 2000; Zahra, 2005). Consistent with agency theory's emphasis on the design of appropriate incentive structures (Eisenhardt, 1989), the majority of these studies analyze how innovation is related to CEO compensation and ownership (e.g., Fong, 2010). For example, Makri et al. (2006) found a positive relationship between citations of firm patents and CEO compensation. Few studies integrate agency theory with other theories, such as the resource-based view (Balkin, Markman, & Gomez-Mejia, 2000; Kor, 2006; Qian, Wang, Geng, & Yu, 2017) or upper echelons theory (Heyden, Reimer, & van Doorn, 2017; Kor, 2006).

The authors apply other theoretical lenses much less frequently. These include, for instance, the resource-based view (e.g., Eisenhardt & Schoonhoven, 1996; Somaya, Williamson, & Zhang, 2007). Building on the notion that a firm's unique resources create sustainable competitive advantages (Barney, 1991), a few scholars investigate the impact of firm resources, such as social capital (Kemper, Schilke, & Brettel, 2013) and R&D management capabilities (Deeds, DeCarolis, & Coombs, 2000), on innovation outcomes. Other studies based on leadership theory investigate the relationship between specific types of leadership and technological innovation (e.g., Osborn & Marion, 2009). Scholars occasionally employ other theoretical lenses, such as the attention-based view (Koryak, Lockett, Hayton, Nicolaou, & Mole, 2018; Maula, Keil, & Zahra, 2013) or resource-dependence theory (Datta & Guthrie, 1994; Wu, 2008). Kalyta (2009) combined findings from managerial hegemony and optimal contracting theory to deduce compensation transparency theory. The author found that CEOs with supplemental retirement plans contingent on firm performance reduce R&D investments as they approach retirement. H. Li et al. (2007) used procedural justice theory and found that a higher degree of perceived procedural justice in the TMT's decisions is positively related to the performance of newly developed products. G. Chen et al. (2005) drew from the theory of cooperation and competition (Deutsch, 1973, 2011) and found that cooperative conflict management among the TMT positively affects the TMT's effectiveness and innovation outcomes, whereas competitive and conflict-avoiding approaches have the opposite effect.

	Upper echelons theory	Agency theory
Strategic leaders in focus	• CEO • TMT (group)	• Board (group) • CEO
Key attributes of strategic leaders analyzed	CEO • Demographics and experience • Personality • Attention and perception TMT • Demographics and experience • Collaboration and behavior	Board • Demographics and experience • Composition and structure • Networks CEO • Demographics and experience • Incentives
Exemplary articles	Barker & Mueller, 2002; Heavey & Simsek, 2015; Lyngsie & Foss, 2017; Srivastava & Lee, 2005; Talke et al., 2011	Chen & Hsu, 2009; Flammer & Bansal, 2017; Hoskisson et al., 2002; Makri et al., 2006; Robeson & O'Connor, 2013
Supplemental theories used, including exemplary articles	• Agency theory (Heyden et al., 2017; Kor, 2006) • Leadership theories (Elenkov et al., 2005; Makri & Scandura, 2010) • Personality theory (Gerstner et al., 2013) • Resource dependence theory (Datta & Guthrie, 1994; Shi et al., 2018) • Resource-based view (Kor, 2006) • Social learning theory (Kraft & Bausch, 2016)	• Behavioral theory of the firm (Souder & Bromiley, 2017) • Labor market theory (Fong, 2010) • Network theory (Kang & Zaheer, 2018) • Resource-based view (Balkin et al., 2000; Kor, 2006; Qian et al., 2017) • Resource dependence theory (Dalziel et al., 2011; Wu, 2008) • Stewardship theory (Zona, 2016) • Upper echelons theory (Heyden et al., 2017; Kor, 2006)

Selected other employed theories

- Attention-based view (e.g., Kammerlander & Ganter, 2015; Koryak et al., 2018; Maula et al., 2013)
- Behavioral theory of the firm (e.g., Lim & McCann, 2014; Miller & Triana, 2009; Souder & Bromiley, 2017)
- Compensation transparency theory (Kalyta, 2009)
- Leadership theories (e.g., Chen, Tang et al., 2014; Jung et al., 2008; Osborn & Marion, 2009)
- Procedural justice theory (Li et al., 2007)
- Resource-based view (e.g., Chen et al., 2016; Eisenhardt & Schoonhoven, 1996; Kemper et al., 2013)
- Resource dependence theory (e.g., Arzubiaga et al., 2018; Chen, 2014; Howard et al., 2017)
- Social identity theory (Jansen et al., 2016)
- Social network theory (Cao et al., 2006; Kraft & Bausch, 2018)
- Stewardship theory (e.g., Arzubiaga et al., 2018; Zona, 2016)
- Theory of cooperation and competition (Chen et al., 2005)

FIGURE 3 Main theoretical lenses. CEO, chief executive officer; TMT, top management team

Finally, some articles do not explicitly adopt a theoretical lens and put little emphasis on extant theory. Many of those studies stem from the fields of finance and economics (e.g., Chen, Podolski, Rhee, & Veeraraghavan, 2014; Dang & Xu, 2018; Frydman & Papanikolaou, 2018). The most likely explanation for this observation is differences in academic conventions across fields.

3.2 | Innovation-related constructs

As mentioned above, we distinguish among innovation input, output, and processes. In addition, we identify several constructs related to the intraorganizational context. We first introduce the innovation-related constructs before reviewing the relationships between these constructs and strategic leaders' characteristics.

3.2.1 | Innovation input

Most studies of innovation input focus on R&D measures. Scholars mainly measure R&D intensity, which is the firm's R&D investments scaled by a firm-specific factor, such as sales (e.g., Cassell, Huang, Sanchez, & Stuart, 2012), the book value of assets (e.g., Flammer & Bansal, 2017; Hirshleifer, Low, & Teoh, 2012), the firm's market value (e.g., Celikyurt, Sevilir, & Shivdasani, 2014), or the number of employees (e.g., Baysinger, Kosnik, & Turk, 1991; Deutsch, 2007). Some authors use absolute R&D investments owing to certain features of their sample or research setting (e.g., Dalziel, Gentry, & Bowerman, 2011; Rose, Rose, Norman, & Mazza, 2014) or to complement their analysis of R&D intensity (e.g., Jung, Chow, & Wu, 2003).

A few authors investigate the external adoption of technologies. In that regard, most scholars use variables related to research alliances that create opportunities for firms to obtain innovation input. Whereas some scholars analyze the number of formed alliances (Eisenhardt & Schoonhoven, 1996; Howard, Withers, & Tihanyi, 2017) or whether companies would hypothetically form or did form an R&D alliance (Sullivan & Tang, 2013; Tyler & Steensma, 1998), Kang and Zaheer (2018) examined the network distance between research alliance partners (i.e., the length of the shortest path between the partners in an alliance before the actual formation of that alliance). Other researchers analyze additional aspects of technology adoption. For example, Gerstner et al. (2013) investigated the number of new strategic initiatives, ranging from the formation of research alliances and internal R&D projects to the acquisition of new technologies.

3.2.2 | Innovation output

With regard to innovation output, researchers primarily consider the number of patents (e.g., Balsmeier, Buchwald, & Stiebale, 2014; Mao & Zhang, 2018) and patent citations (e.g., Faleye, Hoitash, & Hoitash, 2011; Martin, Washburn, Makri, & Gomez-Mejia, 2015). Most studies that analyze the number of patents use them as a proxy for innovation quantity or innovation activities (e.g., Jung, Chow, & Wu, 2003; Makri & Scandura, 2010). Kaplan (2008a), for example, analyzed the degree to which firms invest in new technological fields by comparing the number of patents in those fields with the firms' total number of patents. All studies in our sample that rely on patent data count the number of granted patents instead of patent applications owing to data availability, but they use the patent application date to determine when the innovation activity took place (Wu, Levitas, & Priem, 2005).

As patent counts do not account for variations in the technological and economic impacts of different patents (Hall, Jaffe, & Trajtenberg, 2005), scholars often use patent citations to measure innovation output. First, scholars use patent citations as a supplementary proxy for innovation output that accounts for output quality (e.g., Chen, Podolski, Rhee, & Veeraraghavan, 2014; Sunder, Sunder, & Zhang, 2017). Second, some scholars conduct more nuanced analyses of innovation output through patent citations (e.g., Cremers, Litov, & Sepe, 2017; Faleye, Hoitash, & Hoitash, 2011). For instance, Cho and Kim (2017) identified patents with the largest number of forward citations and classify them as breakthrough innovations with high impacts in specific technological fields.

Other scholars examine the introduction of new products, services, or processes. Some simply count the number of such introductions (e.g., Li, Maggitti, Smith, Tesluk, & Katila, 2013; Lyngsie & Foss, 2017; Nadkarni & Chen, 2014). A few researchers analyze the point in time at which firms introduce a new offering (Eggers & Kaplan, 2009; Haneda & Ito, 2018; Srivastava & Lee, 2005). Others use additional measures based on products, services, and processes developed by firms, such as the percentage of revenue attributable to innovation output (Mihalache, Jansen, van den Bosch, & Volberda, 2012) or the degree of innovativeness in innovation output (e.g., Cook & Glass, 2015; Talke, Salomo, & Kock, 2011). Notably, few authors specifically consider processes in their analyses (Haneda & Ito, 2018; Qian, Cao, & Takeuchi, 2013; Swink, 2000).

3.2.3 | Innovation process

A few scholars analyze the links between innovation input and output. Some either directly assess the firm's product-development capabilities (Brentani & Kleinschmidt, 2004; Kleinschmidt, Brentani, & Salomo, 2007; Swink, 2000) or use measures that combine aspects of innovation input- and output-related constructs to evaluate a firm's development capabilities (e.g., Kemper, Schilke, & Brettel, 2013).

Other scholars analyze innovation efficiency. More specifically, they measure patent output relative to R&D investments (e.g., Bannò, 2016; Chemmanur, Kong, Krishnan, & Yu, 2019; Galasso & Simcoe, 2011) to evaluate the degree to which firms transform innovation input into output. Still other scholars analyze the firm's output elasticity, which is defined as changes in revenue resulting from changes in R&D (Cremers, Litov, & Sepe, 2017).

3.2.4 | Intraorganizational innovation context

Some researchers investigate the underlying intraorganizational innovation context. We identify two key factors in this regard. First, researchers study executives' influence on innovation, often using surveys directed at the CEO (Elenkov, Judge, & Wright, 2005) or the TMT (Elenkov & Manev, 2005; Hegarty & Hoffmann, 1990; Hoffman & Hegarty, 1993). Second, scholars frequently analyze firms' innovation orientation or innovation culture. Most of these researchers focus on the ambidextrous orientation of firms, or the degree to which firms emphasize exploratory or exploitative innovation (e.g., Cao, Simsek, & Zhang, 2010; Ou, Waldman, & Peterson, 2018; Tuncdogan, van den Bosch, & Volberda, 2015). Most scholars employ survey-based measures to study this organizational factor (e.g., Chen, Tang, Cooke, & Jin, 2016; Heavey, Simsek, & Fox, 2015; Kammerlander, Burger, Fust, & Fueglistaller, 2015). A few also analyze patent citations to distinguish between firms' exploratory and exploitative innovation efforts (e.g., Balsmeier, Fleming, & Manso, 2017; Custódio, Ferreira, & Matos, 2019). Finally, some studies directly measure firms' innovation culture using survey-based measures (Berson, Oreg, & Dvir, 2008; Zhang, Ou, Tsui, & Wang, 2017).

3.3 | The relationship between strategic leaders and technological innovation

Various studies illuminate the innovation-related effects of individual- and group-level characteristics of the board, characteristics of the CEO, and individual- and group-level characteristics of the TMT.

3.3.1 | Individual-level board member characteristics

Relatively little research has focused on the impact of individual directors' characteristics on technological innovation. In fact, we identified research on only one situation in this regard—when the board's chairperson is an outside director, a case often referred to as "CEO nonduality" (e.g., Finkelstein & D'Aveni, 1994; Zona, 2016). The key idea in these studies is that outside board chairs can align the interests of management and shareholders to mitigate agency problems, which are particularly prevalent in the innovation context owing to the inherent risk and uncertainty. Kor (2006), for example, reported a positive relationship between CEO nonduality and innovation input, suggesting that outside chairpersons might be able to encourage management to focus on long-term investments. Zona (2016) identified CEO tenure as a moderator of this relationship, finding that CEO nonduality increases R&D investments in case of long CEO tenure but reduces them in cases of short CEO tenure. He suggests that board power can only amplify R&D investments when the CEO has secured sufficient discretion through longer tenure. Other research finds that CEO nonduality strengthens the effects of CEO stock ownership (Lim, 2015) and family ownership (Chen & Hsu, 2009) on innovation outcomes. Balsam et al. (2016) studied the reverse relationship—how innovation affects strategic leaders. They find that R&D-intensive firms are more likely to have an outside board chair, and they argue that shareholders of such firms might prefer an outside chairperson to ensure oversight over management. Overall, Balsam et al.'s (2016) findings suggest that Kor's results should be treated with caution.

3.3.2 | Group-level board characteristics

More research has examined the board's group-level *demographic characteristics* in the context of technological innovation. Generally, this stream of research finds a positive relationship between gender and racial diversity and innovation outcomes, as such diversity might contribute novel perspectives and ideas to board discussions (Bernile, Bhagwat, & Yonker, 2018; Miller & Triana, 2009). Cook and Glass (2015) found that the positive association between board diversity and product innovation was particularly important in a sample of US firms "when a White CEO operates with a diverse board" (p. 117).

With regard to board members' prior *experience*, research finds that the innovation outcomes of work-related experience and education-related experience differ. *Work experience* in other firms and industries influences directors' decisions on complex strategic issues, including technological innovation. In this regard, firms show higher innovation input and output when they have a higher number of outside directors with work experience in patent-intensive firms (Balsmeier, Buchwald, & Stiebale, 2014) or with technical, research-related work experience (Dalziel, Gentry, & Bowerman, 2011; Haneda & Ito, 2018). Dalziel et al. (2011) showed that directors' entrepreneurial finance experience is negatively related to R&D investments—such experience might lead directors to focus on cost-effective research practices. The implications of *educational experience* are less clear. Whereas an elite education among directors is positively linked to innovation input, outside directors with a doctoral-level education, which should equip them with research-related skills, is surprisingly negatively related to innovation input (Dalziel, Gentry, & Bowerman, 2011). The same authors find no link between inside directors' doctoral degrees or entrepreneurial finance experience and R&D investments—stressing the need to distinguish between inside and outside directors.

A considerable body of work studies the effects of board *composition and structure* on technological innovation. Most studies investigate the impact of board independence on innovation outcomes by analyzing the ratio of outside directors to inside directors. In his meta-analysis, Y. Deutsch (2005) found a negative relationship between this ratio and innovation input. Notably, these findings contradict traditional agency theory, which highlights the importance of outside directors in reducing managers' reluctance to invest in risky, long-term innovation activities (David, Hitt, & Gimeno, 2001; Jensen & Meckling, 1976). One explanation might be that outside directors prefer external innovation acquisition because they have limited knowledge of internal R&D processes (Hoskisson, Hitt, Johnson, & Grossman, 2002). Moreover, Zona (2016) provided evidence that the negative relationship between the outsider ratio and innovation input might be contingent on CEO tenure, as he observes positive effects at later stages of CEO tenure. Relatedly, Osma (2008) showed that a higher number of outside directors can lower the tendency of CEOs to reduce R&D investments when their firms face reduced earnings or losses. With regard to innovation output, research finds a positive relationship between the outsider ratio and both an organization's overall patenting activities and exploitative innovation, indicating that intensified monitoring by outside directors might push managers to focus on less risky, more quantifiable innovation output (Balsmeier, Fleming, & Manso, 2017). Partly supporting this argument, Arzubiaga et al. (2018) showed that the board's engagement in monitoring and advising amplifies the relationship between entrepreneurial orientation and ambidextrous innovation in a sample of Spanish family firms.

Additional findings on the impact of directors' family membership on innovation outcomes highlight the importance of the firm and corporate-governance contexts. On the one hand, Matzler et al. (2015) found that family presence on the supervisory boards of German firms decreases innovation input and strengthens innovation output, suggesting higher innovation efficiency. On the other hand, Bannò (2016) identified a negative relationship between the share of family representatives on the boards of Italian family firms and innovation efficiency.

Board *incentives* have been studied only as they relate to stock ownership. First, studies indicate that board incentives can help increase the board's monitoring activities and, thereby, counter CEOs' risk aversion.[1] In particular, higher proportions of stock ownership by outside directors seem to curb the tendency of CEOs with more stock ownership to reduce R&D investments (Lim, 2015). Moreover, higher values of outside directors' stock options intensify the tendency of firms to increase R&D investments if they experience a decline in returns on assets (Lim & McCann, 2014). Second, research suggests that outside directors' limited knowledge of internal innovation processes and capabilities affects their decision making. Hoskisson et al. (2002) showed that outside directors' stock ownership is positively associated with the acquisition of external innovations, whereas inside directors' stock ownership is positively related to internal innovation. Along the same lines, Kang and Zaheer (2018) found that outside directors' stock ownership is positively associated with firms choosing partners for R&D alliances that have no prior ties to the focal firm.

Finally, scholars have studied the implications of boards' *networks* and social ties, and they found that such social capital typically makes it easier for organizations to acquire necessary resources. First, board interlock ties facilitate the formation of R&D alliances between the interlocked firms (Howard, Withers, & Tihanyi, 2017; Sullivan & Tang, 2013). Second, ties to other firms provide boards with information relevant for their tasks. Although a greater number of ties to high-technology firms enable directors to ensure the cost-efficient usage of R&D funds, stronger ties to low-technology firms have the opposite effect (Dalziel, Gentry, & Bowerman, 2011). M. Li (2019) showed that both industry diversity in board ties and board interlocks with R&D-intensive firms increase the likelihood that firms engage in technological exploration. However, M. Li also found that the ratio of interlocks among directors with output functional experience is negatively associated with technological exploration, suggesting that interlocks among directors with this experience might be less important for technological innovation. Third, some ties hinder innovation. As Rose et al. (2014) showed, this seems to be the case for directors' intraorganizational friendship ties with the CEO, which are positively related to reductions in innovation investments aimed at providing short-term benefits to the CEO. Noticeably, this effect increases with the disclosure of such ties (Rose, Rose, Norman, & Mazza, 2014), highlighting the reputational effects of social relationships in firm governance.

3.3.3 | Individual-level CEO characteristics

A large body of research analyzes CEO characteristics in the context of innovation. Several studies investigate *demographic characteristics* as proxies for CEOs' cognitive frames (Hambrick, 2007). In this regard, various scholars find detrimental effects of age and tenure on CEOs' risk appetite, ability to process new information and, consequently, innovation activities. The longer a CEO is in office, the less that CEO is willing to invest in technological innovation—CEOs with longer tenures are more committed to established paradigms, and they tend to emphasize stability over technological change (Barker & Mueller, 2002; Zahra, 2005). Cheng (2004) demonstrated that compensation committees aim to alleviate this career-horizon problem by more closely linking R&D spending to compensation for older CEOs. Moreover, high CEO age and a limited career horizon are associated with both reduced innovation input and output, as older CEOs might be less inclined to embrace new ideas and organizational changes (Barker & Mueller, 2002; Heyden, Reimer, & van Doorn, 2017; Kalyta, 2009). These findings also suggest that the reduced investments in R&D by older and longer tenured CEOs are not an indicator of greater innovation efficiency but rather a reflection of the preference of those CEOs to engage in short-term investments. In support of this argument, Cho and Kim (2017) found that the reduction in R&D investments mediates the negative relationship between CEO tenure and innovation output.

Work and educational experience are also related to CEOs' decision making regarding innovation (Barker & Mueller, 2002). *Work experience* in output functions that are characterized by an emphasis on business growth through the development of new products or new markets seems to lead CEOs to favor innovation strategies and is, consequently, associated with increased R&D spending. With regard to *educational experience*, there is a positive relationship between the CEO's number of science or engineering degrees and R&D expenditure, whereas the overall education level and number of business degrees have no significant effects as long as the CEO holds a college degree. However, this relationship might be driven by reverse causality, as Datta and Guthrie (1994) found that R&D-intensive firms are more likely to select CEOs with technical experience and a higher level of education.

Moreover, studies indicate a significant impact of CEO *personality* on innovation outcomes. Interestingly, although not surprising given the potentially glamorous but risky nature of technological innovation, firms' technological innovation outcomes seem to be a function of CEO personality traits related to risk seeking, a sense of superiority, and a desire for attention or acclaim, that is, sensation-seeking (Sunder, Sunder, & Zhang, 2017), overconfidence (Galasso & Simcoe, 2011; Hirshleifer, Low, & Teoh, 2012), hubris (Tang, Li, & Yang, 2015), and narcissism (Gerstner, König, Enders, & Hambrick, 2013), the latter also in paradoxical combination with humility (Zhang, Ou, Tsui, & Wang, 2017). Apparently, innovation requires narcissistic tendencies, which allow a CEO to derive utility from attention and to be less hesitant to invest despite unfavorable odds and substantial resource rigidity in organizations (Gerstner, König, Enders, & Hambrick, 2013; Gilbert, 2005). Furthermore, H. Zhang et al. (2017) found that CEOs' socialized charisma (i.e., their ability to inspire employees and to ensure support for novel routines and practices) mediates the positive interaction effect of high degrees of humility and narcissism on firms' innovation orientation.

Scholars have also examined the cognitive processes through which CEOs attend to and perceive their environment. First, studies show that CEO *attention* to specific technologies or product-development processes affects related innovation outcomes (Calantone, Vickery, & Dröge, 1995; Eggers & Kaplan, 2009). For example, Kaplan (2008a) showed how changes in CEOs' attention to fiber-optic technologies were associated with more patenting activities in this field. Relatedly, CEOs' temporal orientations matter. In dynamic environments, firms are more likely to introduce new products when the CEO is focused on the present and the future. In stable environments, firms are more likely to do so when the CEO is more focused on the past and the present (Nadkarni & Chen, 2014). In an examination of personality traits, attention, and innovation outcomes, Gerstner et al. (2013) found that top management's attention to discontinuous innovation is shaped by the CEO's personal preferences. In particular, that level of attention increases with CEO narcissism. In turn, managerial attention mediates the effect of CEO narcissism on discontinuous technology adoption, at least during the technology's era of ferment.

Second, CEOs' *perceptions* of environmental and firm characteristics are related to technological innovation. Kammerlander et al. (2015) observed a positive effect of CEOs' promotion focus on firms' exploration and exploitation activities, as CEOs with high levels of promotion focus aim to maximize their achievements and their firms' competitive position by engaging in long-term exploratory activities and shorter term exploitative activities. Conversely, they show that CEOs' prevention focus—characterized by a desire to avoid failure—is negatively (albeit only marginally significantly) linked to exploration. Martin et al. (2015) found that CEOs' perceptions of firm efficacy moderate the relationship between CEO incentives and innovation output. There is a positive relationship at high levels of perceived firm efficacy because CEOs might pursue innovation to increase their personal wealth. The opposite is true for low levels of perceived efficacy. With respect to perceived environmental characteristics, Lefebvre et al. (1997) showed that perceived environmental dynamism increases the positive effects of a firm's technology policy (i.e., the degree to which a firm pursues technological changes and recruits relevant human resources) on innovation outcomes, whereas higher perceived hostility has negative effects on such policies, likely because it reduces investments with long payoff horizons.

The CEO's *leadership* style also influences technological innovation outcomes. The most studied leadership style in this context is transformational leadership, which positively affects innovation outcomes (Elenkov & Manev, 2005; Jung, Chow, & Wu, 2003; Jung, Wu, & Chow, 2008). This is not surprising given that the key elements of transformational leadership—charisma, idealized influence, and intellectual stimulation—enable leaders to elicit commitment from subordinates and drive employees' creativity (Jung, Wu, & Chow, 2008; Oldham & Cummings, 1996). Various organizational and environmental characteristics strengthen the relationship between transformational leadership and innovation outcomes, including an organizational climate of support for innovation, lower centralization and formalization within the organization, and higher degrees of competition and environmental uncertainty (Jung, Wu, & Chow, 2008). Y. Chen et al. (2014) highlighted the role of corporate entrepreneurship (i.e., a firm's venturing and renewal activities) as a mechanism through which transformational CEOs improve innovation practices. They argue that transformational CEOs encourage employees to reconsider established routines and foster new business venturing, which improves the odds of corporate entrepreneurship in the organization. They consequently find that corporate entrepreneurship mediates the relationship between transformational leadership and product innovation.

Other research explores the differences between transformational and transactional leadership, where the latter is characterized by a focus on clearly defined goal/reward systems for subordinates (Jansen, Vera, & Crossan, 2009). Elenkov and Manev (2005) identified generally positive effects of both leadership styles on organizational innovation. Jansen et al. (2009) found that transformational leadership positively affects exploratory innovation, whereas transactional leadership reduces flexibility and creativity and, thus, engenders exploitative innovation.

Research concerning other aspects of the relationship between CEO leadership styles and innovation is more limited. Elenkov and Manev (2005) found that laissez-faire leadership is negatively associated with organizational innovation, whereas they find no effects of active or passive management by exception. Makri and Scandura (2010) showed a significant positive interactive effect of creative and operational leadership on innovation quantity in high-tech firms, and they demonstrate that the highest levels of innovation quantity are achieved when both leadership dimensions are high. They find no effect on innovation quality and that only creative leadership (not operational leadership) is positively related to the use of science in innovation.

Various studies analyze the relationship between CEO *incentives* and innovation outcomes. Many of these studies focus on CEO *compensation* and argue that firms reward CEOs for risky, long-term investments in innovation. For example, studies find that innovation outcomes are positively associated with total CEO compensation (Makri, Lane, & Gomez-Mejia, 2006) and long-term option compensation (Baranchuk, Kieschnick, & Moussawi, 2014; Cheng, 2004). Other studies account for specific requirements in research-intensive industries and find a positive link between innovation input and output and short-term CEO compensation (Balkin, Markman, & Gomez-Mejia, 2000). In exploring the reverse relationship, Fong (2010) found that relatively underpaid CEOs in R&D-intensive industries are associated with higher R&D spending, whereas lower innovation input is evident when CEOs are underpaid in less R&D-intensive industries. The underlying argument is that CEO compensation and R&D investments are better aligned in R&D-intensive industries. Research investigating broader cross-industry samples suggests nuanced effects of different compensation components on innovation outcomes. Whereas compensation-based risk incentives are positively associated with innovation output (Mao & Zhang, 2018), large CEO inside debt holdings (Cassell, Huang, Sanchez, & Stuart, 2012) and deferred compensation and pension benefits (Kalyta, 2009) can reduce risk-seeking behavior and, in turn, diminish innovation input.

Several scholars analyze CEO *stock ownership* or *stock options*. On the one hand, there is a positive relationship between CEOs' general firm ownership and innovation outcomes (Barker & Mueller, 2002; Gedajlovic, Cao, & Zhang, 2012). On the other hand, higher values of stocks and options to be exercised in the short term (Edmans, Fang, & Lewellen, 2017) and increasing values of restricted stock (Lim, 2015) are negatively associated with R&D intensity. Some scholars include additional characteristics of the focal firm or its strategic leaders in their analyses. For example, Lim (2015) found that increased board vigilance due to a higher proportion of outside directors with more stock options can alleviate the negative relationship between higher restricted stock values of CEOs and their firms' R&D investments. Similarly, Zona (2016) demonstrated that incentivizing CEOs through stock options can mitigate the detrimental effects of CEOs' career horizons on innovation outcomes. Gedajlovic et al. (2012) attempted to identify the causal mechanisms linking CEO ownership with innovation outcomes by exploring the mediating effect of the degree to which the TMT engages in comprehensive decision making. The authors argue that CEO shareholdings, as a proxy for management shareholdings, incentivize managers to engage in comprehensive decision-making procedures. In their study of a sample of Chinese high-tech small- and medium-sized enterprises, they find that the TMT's decision comprehensiveness partially mediates the positive relationship between CEO stock ownership and ambidextrous innovation.

Finally, research points to both positive and mimetic effects of CEOs' *network* ties and social capital in the innovation context. The size of a CEO's network facilitates access to relevant information and can positively affect the firm's innovation outcomes (Cao, Simsek, & Zhang, 2010; Faleye, Kovacs, & Venkateswaran, 2014). In addition, CEOs' outside directorships foster strategic imitation and result in similar R&D intensity in the CEOs' home firms—an effect that increases with the tenure of CEOs as outside directors (Oh & Barker, 2018).

3.3.4 | Individual-level TMT member characteristics

Few researchers examine the individual characteristics of top executives other than the CEO. Scholars find that firms' innovation activities can have a positive impact on the *appointment* of chief diversity officers (Shi, Pathak, Song, & Hoskisson, 2018) and the *compensation* of chief marketing officers (Bansal, Joseph, Ma, & Wintoki, 2017). Garms and Engelen (2019) highlighted a positive link between chief technology officers' (CTOs') level of structural *power*, which is derived from their hierarchical position in the TMT and affects their influence on the TMT's decision making, and innovation outcomes. The same authors demonstrate that CTOs' expert power, which originates from their technical expertise, is negatively related to innovation outcomes, and they suggest that CTOs high in expert power might be more aware of innovation-inherent risks.

3.3.5 | Group-level TMT characteristics

More research examines the TMT as a group in the context of technological innovation. Some of these studies investigate the TMTs' *demographic* characteristics. Although Bantel and Jackson (1989) did not find a significant direct effect of TMT age on innovation adoption, higher mean TMT age can aggravate the negative effect of a CEO's short career horizon on R&D intensity (Heyden, Reimer, & van Doorn, 2017). Relatedly, and similar to the findings regarding CEO tenure, a negative link exists between longer TMT tenure and R&D intensity (Kor, 2006). On the other hand, the benefits of knowledge derived from a longer tenure might outweigh inertial effects in high-tech industries. For instance, Srivastava and Lee (2005) found that longer TMT tenure results in slower new product introductions and a lower likelihood of becoming an industry's first mover in product introductions in the telecom and brewing industries, whereas the opposite is true in the computer industry. J. Chen et al. (2019) also measured TMT tenure diversity and find a positive relationship between TMT tenure diversity and organizational ambidexterity.

Moreover, TMT *education* affects innovation outcomes. Science or engineering degrees (Scherer & Huh, 1992) as well as a higher level of education in the TMT (Bantel & Jackson, 1989; Heyden, Reimer, & van Doorn, 2017) can foster innovation. In contrast, Deeds et al. (2000) found a marginally significant negative relationship between the share of TMT members with doctoral degrees and the number of new products developed, which hints at potentially detrimental effects when technical talents move from the laboratory to management positions. Furthermore, Heyden et al. (2017) found that a higher educational level in the TMT does not alleviate CEO horizon problems.

With regard to the prior *work experience* of TMT members, when the TMT is experienced in specific topics or industries, it generally has a stronger focus on innovation activities related to those topics or industries (e.g., Hoffman & Hegarty, 1993; Somaya, Williamson, & Zhang, 2007; Urbig, Bürger, Patzelt, & Schweizer, 2013). For example, Tyler and Steensma (1998) found a positive relationship between the technical work experience of TMT members and their assessments of potential research alliances. Kor (2006) found a positive relationship between shared experiences among TMT members and technological innovation. In addition, heterogeneity in TMT members' functional backgrounds moderates the relationship between the board's outsider ratio and the firm's R&D intensity—for higher levels of TMT functional heterogeneity, the board's outsider ratio is increasingly negatively related to R&D intensity, whereas there is an increasingly positive relationship for lower levels of heterogeneity (Kor, 2006).

Other research specifically analyzes diversity in the TMT's demographic characteristics, such as the share of females (Dezsö & Ross, 2012); nationality diversity (Boone, Lokshin, Guenter, & Belderbos, 2019); and heterogeneity in educational, functional, industry, and organizational backgrounds (Talke, Salomo, & Kock, 2011). This research generally finds positive links between such types of diversity and innovation outcomes. However, Lyngsie and Foss (2017) cautioned that the positive association between a higher share of female top managers and innovation outcomes only occurs above a certain threshold, whereas the initial addition of female TMT members is even negatively associated with innovation outcomes.

Studies investigating TMT *composition and structure* mainly focus on the impact of TMT size on decision-making speed and processes (West & Anderson, 1996). A larger TMT is positively linked to alliance formation, as it is more likely to have the required resources, such as connections to potential partners (Eisenhardt & Schoonhoven, 1996). In addition, firms with larger TMTs are more likely to be the first to introduce new products in an industry (Srivastava & Lee, 2005).

Some studies examine TMT composition and structure in the context of family firms. Matzler et al. (2015) showed that the number of family members in the TMT can positively affect innovation input and output. Notably, Vandekerkhof et al. (2015) demonstrated that a higher degree of firm innovation increases the need for the expertise of nonfamily TMT members. However, for firms with high levels of socioemotional wealth and thus a focus on family-related objectives, they find that the degree of innovation has no impact on the appointment of nonfamily TMT members. Moreover, Kraiczy et al. (2015) found a positive moderating effect of TMT family members' closeness to the first or founding generation on the relationship between the CEO's risk-taking propensity and product innovation.

Beyond demographic variables and TMT composition, research is increasingly focused on *collaboration and behavior* within the TMT in the context of technological innovation. This literature highlights the importance of cooperation within the TMT for managing complex innovation processes (Chen, Tjosvold, & Liu, 2006). In that regard, behavioral integration (Halevi, Carmeli, & Brueller, 2015; Lubatkin, Simsek, Ling, & Veiga, 2006), a shared vision and social integration (Jansen, George, van den Bosch, & Volberda, 2008), and general TMT integration (Ou, Waldman, & Peterson, 2018) can be beneficial for innovation outcomes, especially in the context of ambidextrous innovation that requires the balancing of partly contradictory exploitative innovation and explorative innovation. For instance, Ou et al. (2018) found that TMT integration (i.e., collaboration, information sharing, and joint decision making within the TMT) partially mediates the impact of CEO–TMT pay disparity in that pay disparity negatively relates to TMT integration, but TMT integration positively relates to ambidextrous innovation. Finally, collaborative behavior is important in the context of conflict management in the TMT (e.g., Qian, Cao, & Takeuchi, 2013). For example, G. Chen et al. (2005) found that cooperative conflict management in the TMT improves team effectiveness and, thereby, innovation outcomes.

Several authors explore the ways in which the TMT works and the activities on which it focuses (e.g., Alexiev, Jansen, Bosch, & Volberda, 2010; Li, Bingham, & Umphress, 2007). For example, Heavey and Simsek (2017) found that the TMT's transactive memory—its ability to efficiently generate, distribute, and integrate knowledge based on individual managers' expertise—is positively related to organizational ambidexterity. As another example, Q. Li et al. (2013) found a positive relationship between the degree to which TMT members conduct innovation searches in unfamiliar and distant terrains and new product introductions, whereas the extent to which TMTs engage in effortful search is negatively related to this innovation outcome.

Furthermore, in line with the findings for board and CEO incentives, TMT *compensation* can compel managers to incorporate long-term considerations, like innovation, into their decision making. In that regard, higher total annual TMT compensation is positively related to firms' R&D intensity (Zhang, Chen, & Feng, 2014). In addition, the value of TMTs' exercisable stock options is positively related to firms' R&D spending, as managers might anticipate a positive reaction of investors to increased R&D investments (Souder & Bromiley, 2017). In contrast, short-term performance incentives are negatively associated with R&D intensity (Hoskisson, Hitt, & Hill, 1993). However, studies investigating the reverse relationship highlight the importance of considering potential endogeneity, as higher R&D intensity is related to an increased duration of executive compensation, that is, a longer average vesting period of the TMT's compensation components (Gopalan, Milbourn, Song, & Thakor, 2014), and higher values of firm patents are associated with higher average TMT compensation (Frydman & Papanikolaou, 2018).

Finally, some research investigates whether TMT *network* ties provide executives with valuable information and resources in the innovation context. This research suggests, similar to that on CEO social capital, that substantial managerial ties are beneficial for innovation outcomes (Heavey, Simsek, & Fox, 2015; Kemper, Schilke, & Brettel, 2013). In a meta-analysis, Kraft and Bausch (2018) found that cohesive managerial networks (i.e., small networks with strong ties) are more beneficial for innovation in environments with weak political, regulatory, and financial institutions, whereas diverse networks stimulate innovation in more stable environments.

3.4 | Major contextual moderating factors

The literature review shows that the relationship between strategic leadership and technological innovation also depends on contextual factors. In this regard, we distinguish between environmental and organizational factors (Damanpour & Aravind, 2006).

3.4.1 | Environmental factors

Most studies considering contextual factors analyze environmental factors beyond the organization's boundaries. Some scholars analyze the sociocultural context—with mixed results. Those studies that consider the moderating impact of the firm location do not find a significant influence on the relationships between the TMT's functional role (Hegarty & Hoffmann, 1990), the TMT's experience (Hoffman & Hegarty, 1993), or its leadership behavior (Elenkov, Judge, & Wright, 2005) and innovation outcomes. In contrast, Hofstede's cultural dimensions do moderate the impact of TMT leadership style on innovation (Elenkov & Manev, 2005). Relatedly, Boone et al. (2019) uncovered several partially moderating effects of Hofstede's national power distance on the relationship between the TMT's national diversity and innovation outcomes.

With regard to environmental dynamism, scholars provide stronger, albeit partially inconclusive, evidence of moderating effects. Multiple studies find that environmental dynamism and ambiguity positively moderate the relationship between strategic leaders' characteristics and innovation (Halevi, Carmeli, & Brueller, 2015; Li, Bingham, & Umphress, 2007), which hints at an elevated role of strategic leaders in uncertain environments. Other studies come to the opposite conclusion, although these findings are only marginally significant (Carson, Wu, & Moore, 2012; Kemper, Schilke, & Brettel, 2013).

Moreover, in dynamic environments, shorter CEO tenure (Wu, Levitas, & Priem, 2005) and higher CEO focus on the present and the future (Nadkarni & Chen, 2014) are beneficial for innovation outcomes.

A small number of studies investigate the moderating effects of other environmental factors. Some research considers industry-level characteristics, such as R&D intensity (Fong, 2010) or secrecy regarding innovation activities (Erkens, 2011). For instance, Erkens (2011) found a positive relationship between firms' R&D intensity and TMTs' unvested stock holdings. This relationship is more pronounced in industries with a lower propensity to use patents to protect innovation. Other studies find that competition positively affects the relationship between strategic leadership and innovation outcomes (Jung, Wu, & Chow, 2008; Kammerlander, Burger, Fust, & Fueglistaller, 2015).

3.4.2 | Organizational factors

Organizational characteristics also influence the relationship between strategic leaders and technological innovation. In that regard, the CEO's focus on technologies might compensate for a lack of organizational experience with such technologies (Kaplan, 2008a). Furthermore, firm experience with technological alliances seems to accentuate top executives' willingness to engage in such alliances (Tyler & Steensma, 1998). With respect to organizational gender proportions, Lyngsie and Foss (2017) found that the share of females in the workforce negatively moderates the relationship between the share of female TMT members and innovation outcomes. With regard to organizational culture, Jung et al. (2008) found that an organizational climate of empowerment and support for innovation positively affect the relationship between CEO transformational leadership and innovation, whereas centralization and formalization have the opposite effect. Other scholars find a positive interaction effect between firms' entrepreneurial orientation and various board characteristics on firms' innovation orientation (Arzubiaga, Kotlar, De Massis, Maseda, & Iturralde, 2018) as well as a mediating effect of entrepreneurial orientation between TMTs' transformational leadership style and firms' innovation orientation (Kraft & Bausch, 2016).

3.5 | The impact of technological innovation on performance

Some studies investigate not only the impact of strategic leadership characteristics on technological innovation but also downstream performance effects. We distinguish between innovation- and firm-related performance measures.

3.5.1 | Innovation-related performance measures

Several studies investigate the financial performance of innovations using such measures as contributions to profitability, market share, or sales (e.g., Carson, Wu, & Moore, 2012; Li, Bingham, & Umphress, 2007; Wu, 2008). For example, Cummings and Knott (2018) found that outside CEO succession is negatively related to the firm's ability to generate sales through increased R&D investments, indicating a need for technical expertise and knowledge of internal processes to ensure the successful management of R&D investments. A single study investigates the capital market's reaction to failures in new product development and finds that managerial experience reduces negative market reactions to such failures (Urbig, Bürger, Patzelt, & Schweizer, 2013).

3.5.2 | Firm-related performance measures

Other scholars investigate whether the relationship between strategic leaders and innovation extends to overall firm performance. Several studies find that the positive effects of strategic leaders' characteristics on technological innovation lead to increased firm profitability (e.g., Calantone, Vickery, & Dröge, 1995; Lefebvre, Mason, & Lefebvre, 1997; Miller & Triana, 2009). Others find a positive impact of increased innovation efforts on the firm's market value (e.g., Ammann, Horsch, & Oesch, 2016; Bernile, Bhagwat, & Yonker, 2018; Talke, Salomo, & Rost, 2010).

4 | AN AGENDA FOR FUTURE RESEARCH

Our review highlights numerous avenues for future research, especially with regard to new theoretical lenses on strategic leadership and technological innovation, the role of the board in technological innovation, and the consequences of technological innovation for strategic leaders. Other areas of interest relate to research settings and the measurement of technological innovation, methodological issues, and the implications of current trends in innovation research.

4.1 | Theoretical lenses

An important research opportunity lies in expanding the theoretical perspectives beyond the conceptions of upper echelons and agency theories. As a guide in this direction, scholars could use Georgakakis et al.'s (2019) review on the interaction between the CEO and the TMT, which attempts to integrate upper echelons research with role theory (Biddle, 1986). Scholars could build on Georgakakis et al. to analyze how interactions between the CEO and individual functional executives involved in the innovation process affect innovation outcomes. Moreover, scholars could build on research that criticizes that agency theory might not sufficiently account for the socially situated context in which strategic leaders interact (Westphal & Zajac, 2013). Along those lines, Luciano et al. (2020) recently proposed a novel perspective on interactions between the TMT and the board—the "strategic leadership system"—which highlights the common goals of the TMT and the board while acknowledging their specific responsibilities.

We see great promise in research that adopts a system view of strategic leadership and investigates how the exchange and utilization of experiences and knowledge within and between the board and the TMT contribute to technological innovation.

Some studies already use further well-established theories, such as the resource-based view (e.g., Kemper, Schilke, & Brettel, 2013; Kleinschmidt, Brentani, & Salomo, 2007) or leadership theory (Elenkov, Judge, & Wright, 2005; Osborn & Marion, 2009), to study the link between strategic leadership and innovation. However, scholars could fruitfully draw from a wider variety of alternative theoretical perspectives that have thus far only been sparsely applied. As technological innovation requires shifts in organizational routines and cognitive schemas (König, Graf-Vlachy, & Schöberl, 2020; Tripsas & Gavetti, 2000), it creates potential for conflict within the group of strategic leaders (Kammerlander, König, & Richards, 2018). Therefore, scholars could build on the theory of cooperation and competition (Deutsch, 1973) to study the role of conflicts and conflict management among TMT and board members in the context of technological innovation (Chen, Liu, & Tjosvold, 2005). Compensation transparency theory (Kalyta, 2009) could improve our understanding of the effects of transparency in managerial and board compensation on innovation outcomes. Theories of power (e.g., Sturm & Antonakis, 2015) and paradox (Smith & Lewis, 2011) could help shed light on the intersection of strategic leaders' compensation, behaviors, and personalities with ambidextrous innovation (Ou, Waldman, & Peterson, 2018). Procedural justice theory, as used by H. Li et al. (2007), could improve our understanding of interactions between strategic leaders and other organizational members in the context of technological innovation. As suggested by Jansen et al. (2016), scholars could also consider building on social identity theory (Turner & Tajfel, 1986). Higher degrees of organizational identification among executives may exacerbate inertia, but it might also make executives more motivated to commit to long-term goals and, in turn, engage in organizational innovation activities.

Finally, several relevant theoretical lenses have not yet been used to examine the relationship between strategic leadership and technological innovation. First, this field of study has yet to fully make the "linguistic turn" (Vaara, 2010) that other streams in management studies have made—in other words, a shift towards viewing leadership as emerging through the management of the meaning of organizational events (Clifton, 2012; Gioia & Chittipeddi, 1991) and, in turn, towards the analysis of texts and discursive practices. For example, scholars could investigate how the rhetoric of strategic leaders contributes to sensemaking in organizations (Maitlis & Christianson, 2014) that face technological discontinuities, how strategic leaders legitimize the related organizational changes (Vaara & Tienari, 2008), and how strategic leaders are able to "construct" organizational adaptations to technological change in a positive way (Kaplan, 2008b). Alternatively, discursive approaches could be combined with findings from impression-management research (e.g., Davidson, Jiraporn, Kim, & Nemec, 2004; Graffin, Carpenter, & Boivie, 2011) to study how strategic leaders attempt to satisfy the expectations of internal and external audiences in times of technological change.

Second, scholars could build on new institutionalism (Selznick, 1996) when analyzing strategic leaders in the context of technological innovation. Technological development is an important topic in new institutionalism because the exploitation of novel technologies might require new institutions and established institutions might become salient owing to technological change (Ingram & Silverman, n.d.; Weber, Lehmann, Graf-Vlachy, & König, 2019). Building on institutional theory, scholars could examine the ways in which institutional governance aspects of incumbent organizations, such as hierarchies, rules, procedures, and internal politics, affect strategic leaders' perceptions of uncertainty, their decision making, and their actions in times of discontinuous change. In this context, scholars could also study the antecedents of isomorphism and investigate the characteristics of strategic leaders that inhibit or foster imitation in firms facing technological change (Krause, Wu, Bruton, & Carter, 2019).

4.2 | The role of the board of directors in technological innovation

We identify considerable gaps in our knowledge of the board's role in innovation, which are particularly important given that research recognizes the general impact of boards on firm strategy (Carpenter, Geletkanycz, & Sanders, 2004; Pugliese et al., 2009). Moreover, it is impossible for scholars to generalize findings from extant research on the relationship between the CEO and/or the TMT, and technological innovation to boards, as boards' roles, responsibilities, and agency differ systematically from those of CEOs and other executives (Finkelstein, Hambrick, & Cannella, 2009).

Therefore, we encourage scholars to include boundary conditions of board activities in their research models. As discussed above, most studies on boards in the context of innovation use easily observable characteristics of board composition as proxies for board power, which drives boards' monitoring intensity (Kor, 2006). However, the quality of board monitoring depends on a host of individual-, group-, and firm-level characteristics (Boivie, Bednar, Aguilera, & Andrus, 2016). Treatment of these characteristics as boundary conditions could substantially improve our understanding of strategic leadership and innovation. In addition, scholars may consider constructing alternative measures to capture other relevant properties of the board. For instance, scholars could use surveys to measure boards' strategic involvement and activities (Arzubiaga, Kotlar, De Massis, Maseda, & Iturralde, 2018). Moreover, the effects of board reputation, status, and prestige (Acharya & Pollock, 2020; Oehmichen, Braun, Wolff, & Yoshikawa, 2017) could be an interesting area of research.

We also see a need for a better understanding of the effects of inside and outside directors' education and experience on innovation outcomes (Dalziel, Gentry, & Bowerman, 2011). Research in this regard is limited, and the findings are equivocal. Particularly, it is possible that a higher number of board appointments can severely diminish the beneficial effects of education and experience owing to excessive information-processing demands (Khanna, Jones, & Boivie, 2014).

Therefore, including measures of the board's information-processing demands might shed some light on the innovation-related effects of the board's educational and work experience.

With respect to individual-level board member characteristics, research has thus far only considered CEO nonduality (e.g., He & Wang, 2009; Qian, Wang, Geng, & Yu, 2017), although many other characteristics of outside board chairpersons or other directors might influence innovation. For example, Hambrick et al. (2015) argued that boards with individual directors endowed with sufficient independence, expertise, and motivation as well as the ability to devote time and attention to their tasks might be more successful in preventing governance failures than boards in which these qualities are distributed among directors. As a starting point, scholars could study the impact of individual directors' breadth and depth of work and educational experience (Lungeanu & Zajac, 2019) on innovation outcomes.

Finally, we suggest that researchers address the innovation-related impacts of board subgroups. Only a fraction of the reviewed studies investigate subgroups defined by age, gender, ethnicity, or education (Bernile, Bhagwat, & Yonker, 2018; Cook & Glass, 2015; Dalziel, Gentry, & Bowerman, 2011; Miller & Triana, 2009). However, such subgroups might affect pivotal aspects of innovation. For example, subgroup memberships might have different implications for innovation input and output. Moreover, rather than investigating only direct effects on innovation outcomes, scholars could study how directors' affiliations with specific subgroups affect their behavior and, in turn, innovation outcomes. Clearly, such endeavors would require scholars to develop novel measures and constructs as well as a better understanding of collaboration among board members. In particular, we urge scholars to consider the faultlines literature (Li & Hambrick, 2005), as faultlines between board subgroups might inhibit communication, cohesion, and trust and, thereby, affect innovation decisions (Kaczmarek, Kimino, & Pye, 2012; Tuggle, Schnatterly, & Johnson, 2010).

4.3 | Consequences of technological innovation for strategic leaders

Innovation outcomes might substantially influence strategic leadership, for instance, firms' selection of executives (e.g., Shi, Pathak, Song, & Hoskisson, 2018), CEO nonduality (Balsam, Puthenpurackal, & Upadhyay, 2016), and executive compensation (e.g., Erkens, 2011). In this vein, we see two key avenues for future research on the consequences of firm innovation for strategic leadership. First, additional research could study the innovation-related antecedents of board and TMT composition. For example, scholars could study how and why CEO nonduality and the board's outsider ratio are a function of innovation. In this regard, Y. Deutsch (2005) suggested that the negative impact of the board's outsider ratio on R&D investments might be explained by reverse causality (i.e., by the desire for appropriate board vigilance if the CEO shuns R&D investments). Overall, we suggest that research on the innovation-related determinants of board and TMT composition should also consider the environmental and organizational factors from our framework as well as CEO characteristics (Balsam, Puthenpurackal, & Upadhyay, 2016; Zona, 2016) as potential moderators.

Second, scholars should study the effects of firm innovativeness on the cognitive processes and behaviors of strategic leaders. For example, scholars could study whether firm innovation affects strategic leaders' attention to and perceptions of certain issues (Ocasio, 1997) or could investigate the influence of innovation on the ways in which strategic leaders engage with each other or their employees. In answering such questions, scholars can build on research on managerial and board cognition (Kaplan, 2011; Rindova, 1999) and move beyond studies that merely compare the relationship between strategic leaders' characteristics and innovation in high-tech and low-tech industries (e.g., Srivastava & Lee, 2005).

4.4 | Research settings

Scholars might also use novel research settings to uncover new facets of the relationship between strategic leaders and innovation. Most of the studies reviewed here focus on US firms—few consider samples from other countries (e.g., Barney, Foss, & Lyngsie, 2018; Osma, 2008; Wu, 2008) or multinational samples (e.g., Cheng, 2004; Eggers & Kaplan, 2009; Elenkov, Judge, & Wright, 2005). However, cross-contextual differences (e.g., in cultural and legal aspects) are likely to affect the relationship between strategic leadership and innovation. In fact, local corporate-governance regimes differ substantially in ways that affect boards' discretion and legal obligations (Jungmann, 2006). Scholars might also investigate how directors' affiliations with educational institutions or other organizations affect innovation outcomes across countries owing to a differential influence of such affiliations on director status (Johnson, Schnatterly, Bolton, & Tuggle, 2011).

Moreover, most researchers study multi-industry samples of large, publicly listed firms. Although some find systematic differences in relationships between strategic leaders and innovation when comparing low- and high-tech industries (Srivastava & Lee, 2005), scholars could investigate other aspects of the industry context. For example, the effects of educational background or diversity among strategic leaders might differ between environments that diverge in technology or capital intensity, as they require different skills and capabilities. Scholars could also attempt to reveal idiosyncrasies in the relationship between strategic leaders and innovation in small and medium-sized firms (e.g., Alexiev, Jansen, Bosch, & Volberda, 2010; Lefebvre, Mason, & Lefebvre, 1997; Qian, Wang, Geng, & Yu, 2017).

4.5 | Measurement of technological innovation

We identify several particularly important issues related to the measurement of technological innovation. About two-thirds of the papers in our sample use R&D investments, R&D intensity, or patent-based constructs to measure innovation. Not only are such measures relatively easy to retrieve, replicate, and compare across studies (R. Adams, Bessant, & Phelps, 2006; Hall, Jaffe, & Trajtenberg, 2001; Lerner & Seru, 2017), but they are also recognized as reasonable indicators for firm innovation (Hagedoorn & Cloodt, 2003). However, some scholars suggest that reliance on these R&D-related measures (R. Adams, Bessant, & Phelps, 2006) and firm patent counts (Hall, Jaffe, & Trajtenberg, 2005; Trajtenberg, 1990) as proxies for firms' innovation activities may not be unproblematic. Therefore, we see several research opportunities.

First, scholars should make wider use of alternative measures of innovation input and output. With regard to the former, R. Adams et al. (2006) suggested developing measures that capture tacit input, such as skills and knowledge. Such measures could focus on firms' collaborations with researchers or research institutions, or on the educational background and work experience of firms' R&D staff. With respect to innovation output, scholars should utilize recent developments in text-mining and data-mining techniques to develop more nuanced measures of innovation output. For example, scholars could try to capture the public's perceptions of firms' innovativeness through semantic analyses of press coverage (Graf-Vlachy, Oliver, Banfield, König, & Bundy, 2020), sentiment analyses of social media data (Gautam & Yadav, 2014), or analyses of company rankings (e.g., Forbes, 2018). Alternative ways of determining the quantity and quality of newly developed products, services, and processes could include systematic analyses of trademark filings (Castaldi, 2020), the content and structure of company websites (Mirończuk & Protasiewicz, 2020) or mission statements (Hanisch, Haeussler, Graf-Vlachy, König, & Cho, 2018), firms' 10-K filings (Hoberg & Phillips, 2016), or analyst reports (Bellstam, Bhagat, & Cookson, 2020). Finally, other output-oriented measures could target process innovations, which have rarely been considered in the extant literature (Haneda & Ito, 2018; Qian, Cao, & Takeuchi, 2013; Swink, 2000).

Second, we contend that R&D-based and patent-based measures are still useful for improving our understanding of firms' innovation activities (Hagedoorn & Cloodt, 2003). Nevertheless, we call for greater statistical care with regard to R&D-based measures. The majority of scholars analyze standardized R&D investments (e.g., Heyden, Reimer, & van Doorn, 2017; Kor, 2006). However, using ratios as dependent or independent variables might result in inaccurate parameter estimates (Certo, Busenbark, Kalm, & LePine, 2020). Therefore, we suggest that scholars use unscaled R&D investments and control for the scaling factors when measuring innovation input.

With regard to patent-based measures, it likely makes sense to use citation-based measures of innovation output, at least in addition to simple patent counts (Hall, Jaffe, & Trajtenberg, 2005; Trajtenberg, 1990). Scholars should consider several aspects to ensure empirical validity and allow for comparisons across studies. Some studies include self-citations (e.g., Hirshleifer, Low, & Teoh, 2012), whereas others explicitly exclude such citations (e.g., Faleye, Kovacs, & Venkateswaran, 2014). As Sunder et al. (2017) pointed out, there might be systematic differences among firms that do or do not cite their own patents. Therefore, we suggest that scholars analyze patent citations both ways. In addition, researchers must address the data-truncation problem, which occurs because newer patents are likely to have fewer forward citations than older patents (Hall, Jaffe, & Trajtenberg, 2005). Moreover, researchers must account for differences across technology fields and industries with regard to the propensity to patent (Lerner & Seru, 2017). Most studies in our sample use Hall et al.'s (2001, 2005) adjustment approach (e.g., Custódio, Ferreira, & Matos, 2019; Faleye, Hoitash, & Hoitash, 2011). However, Lerner and Seru (2017) demonstrated that this approach can be problematic. They propose an adapted method that uses patents of publicly traded firms instead of the entire population of patents to adjust for truncation, and they show that this method alleviates at least some of the problems. They also provide a comprehensive checklist for researchers planning to analyze patent data.

Notably, patent-based innovation measures have moved beyond simply counting citations and patent grants (Savage, Li, Turner, Hatfield, & Cardinal, 2020). Several promising approaches may help link firms' technological innovations to strategic leadership characteristics. One possibility is to make use of text-mining techniques by, for instance, comparing patents or patent portfolios. Analyses of textual similarity between patents can be used to track knowledge flows and knowledge spillovers (Arts, Cassiman, & Gomez, 2018; No, An, & Park, 2015). Other options are to measure the novelty of innovations using semantic analyses of patents (Gerken & Moehrle, 2012) or to examine the inventors listed in the firms' patents, for example, to measure human capital quality based on the citations their patents attract (Byun, Oh, & Xia, 2020) or to analyze inventor mobility between organizations (Melero, Palomeras, & Wehrheim, 2020). Finally, scholars could further investigate the circumstances under which firms patent more novel innovations by analyzing the technology classes of patents (Balsmeier, Fleming, & Manso, 2017; Cho & Kim, 2017) or the degree to which firms cite scientific papers in their patents (Makri & Scandura, 2010).

Third, scholars can investigate aspects besides innovation input and output. Few studies examine the relationship between strategic leaders and innovation processes (e.g., Kemper, Schilke, & Brettel, 2013; Kleinschmidt, Brentani, & Salomo, 2007; Swink, 2000), and we have a limited understanding of the factors that allow firms to successfully transform innovation input into output (Duran, Kammerlander, van Essen, & Zellweger, 2016). Future studies could develop measures that will enhance our understanding of how strategic leaders affect innovation processes. With respect to the intraorganizational innovation context, studies to date have merely investigated the ways in which strategic leadership characteristics affect the TMT's influence on innovation (e.g., Elenkov, Judge, & Wright, 2005; Hoffman & Hegarty, 1993). Scholars could extend this logic to the board and analyze the link between specific board characteristics and the board's effect on innovation outcomes.

4.6 | Other methodological issues

Rich and promising avenues for future research also arise from other methodological issues, especially endogeneity and mediation analyses.

4.6.1 | Endogeneity

Accounting for endogeneity in strategic leadership research is "essential for gaining a grasp of the causal mechanisms that lie behind empirical associations" (Hambrick, 2007, p. 338). Aside from measurement error and simultaneity, the key sources of endogeneity in strategic leadership research are omitted variables (Bascle, 2008). In particular, TMT and board member selection are unlikely to be exogenous. The attractiveness of a firm to a strategic leader and the selection of strategic leaders are affected by firm characteristics and prior firm decisions (R. B. Adams, Hermalin, & Weisbach, 2010; Hambrick, 2007). Therefore, any relationship between strategic leadership characteristics and innovation outcomes might be caused by the same hard-to-observe factors that determine board and TMT composition.

Owing to the importance of endogeneity for strategic leadership research, we analyzed how the research in our sample addressed this issue. We built on the main sources of endogeneity outlined by Antonakis et al. (2010) to derive keywords referring to endogeneity.[2] We then read the method and results sections of all articles that contained at least one of these keywords. Figure 4 shows the main results.

The figure highlights the number of papers that methodologically address endogeneity concerns, name endogeneity as a potential limitation when interpreting the results, or do not explicitly address the issue. As illustrated, a number of studies in our sample, especially the earlier ones, do not explicitly account for endogeneity (e.g., Calantone, Vickery, & Dröge, 1995; Hoffman & Hegarty, 1993). If they address endogeneity at all, most studies before 2004 only state that potential endogenous effects should be considered in the interpretation of the results (e.g., Bantel & Jackson, 1989; Hoskisson, Hitt, Johnson, & Grossman, 2002). However, most of the recent studies methodologically address endogeneity (e.g., Ammann, Horsch, & Oesch, 2016; Sunder, Sunder, & Zhang, 2017).

We also found that the quantitative methods used to address endogeneity have evolved over time. Whereas earlier studies often used simple approaches, such as lagging variables or conducting additional subgroup analyses as indicators for causal relationships (e.g., Barker & Mueller, 2002; Deutsch, 2007), recent studies employ more sophisticated methods, such as incorporating fixed effects (e.g., Ammann, Horsch, & Oesch, 2016; Makri, Lane, & Gomez-Mejia, 2006), employing two-stage analyses (e.g., Gerstner, König, Enders, & Hambrick, 2013; Maula, Keil, & Zahra, 2013), or using suitable instrument variables (e.g., Chemmanur, Kong, Krishnan, & Yu, 2019; Kini & Williams, 2012). In addition, some scholars use matched sample approaches (e.g., Ammann, Horsch, & Oesch, 2016; Cremers, Litov, & Sepe, 2017) or examine changes in innovation outcomes after exogenous events, such as exogenous executive turnover (e.g., Balsam, Puthenpurackal, & Upadhyay, 2016; Cummings & Knott, 2018) and regulatory changes (e.g., Balsmeier, Fleming, & Manso, 2017; Mao & Zhang, 2018) or shocks, such as terrorist attacks and the Lehman Brothers bankruptcy (Hutton, Jiang, & Kumar, 2014). In fact, recent papers often employ multiple methods to address endogeneity. For example, Cremers et al. (2017) considered alternative explanatory variables for their dependent and independent variables to reduce potential bias from omitted variables, analyzed multiple matched samples, employed instruments by using the dynamic generalized method of moments estimator, and further examined the effects of an exogenous regulatory change during the observation period.

We strongly advise scholars to use appropriate methods to address endogeneity. Research designs should be constructed to avoid endogeneity from the outset. For instance, longitudinal research designs may be helpful when using archival data

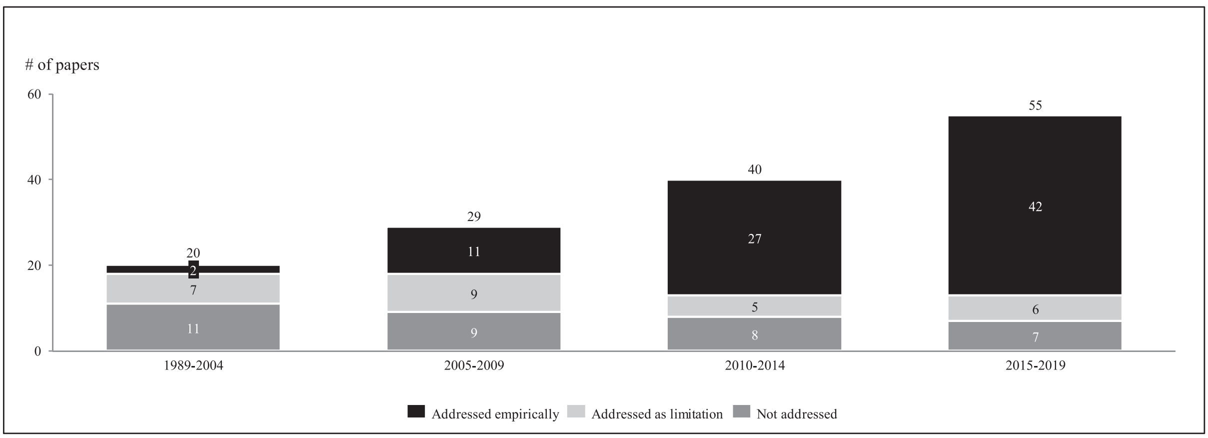

FIGURE 4 Reference to endogeneity as a methodological concern over time

(Hamilton & Nickerson, 2003), and key variables should be measured at different points in time or from different informants in survey-based research. For example, in their survey-based study, Mihalache et al. (2012) collected data for the dependent variables 1 year after collecting data for the independent variables. In addition, scholars could consider using experimental research designs to infer causation. Notably, in our sample, only Rose et al. (2014) conducted an experiment.

Statistical techniques should also be used to account for endogeneity. Whenever possible, scholars should control for potentially confounding variables (Certo, Withers, & Semadeni, 2017). For example, Custódio et al. (2019) used both firm fixed and firm-CEO fixed effects to analyze the impact of CEO managerial skills on innovation output. Heckman-type two-stage models can be helpful in cases of (self-)selection (e.g., when only firms that engage in a certain innovation practice can be observed; Certo, Busenbark, Woo, & Semadeni, 2016; Clougherty, Duso, & Muck, 2016). Instrumental-variable approaches are likely to be the most broadly applicable solution to endogeneity (Hamilton & Nickerson, 2003). Although it can be challenging to find strong and valid instruments (Bascle, 2008), a substantial number of recent studies successfully use them to deal with endogeneity problems (e.g., Chen, Miller, & Chen, 2019; Custódio, Ferreira, & Matos, 2019; Oh & Barker, 2018). For instance, Bernile et al. (2018) measured the relationship between board diversity and innovation outcomes. As their main instrumental variable, they capture the diversity of potential nonlocal directors. Souder and Bromiley (2017) employed five instrumental variables reflecting firm-level compensation policies that are correlated with the potentially endogenous explanatory variables based on TMT stock options. For a particularly detailed discussion and statistical analysis of potential endogenous effects in the relationship between strategic leadership and technological innovation, we refer to Custódio et al. (2019) or Cremers et al. (2017). Notably, both the improved methods for dealing with endogeneity and the relative silence on endogeneity in earlier research create ample opportunities for replication research to ensure that the field's extant findings are robust (Bettis, Helfat, & Shaver, 2016).

4.6.2 | Mediation analysis

Our results show a pressing need to better understand the processes that mediate strategic leadership and innovation outcomes—the proverbial “black box” of strategic leadership research (Lawrence, 1997). In fact, the extant research rarely includes mediation analyses of mechanisms involving the CEO (e.g., Chen, Tang, Jin, Xie, & Li, 2014) or the TMT (e.g., Ou, Waldman, & Peterson, 2018), and most studies on boards to date essentially only analyze the relationship between board composition and technological innovation. Therefore, especially regarding board research, a better understanding of behavioral or collaboration-related variables as well as board processes and dynamics is desirable. For example, future research could build on the initial qualitative research on boards in the context of innovation (Hoppmann, Naegele, & Girod, 2019; Morais, Kakabadse, & Kakabadse, 2019) to deduce potentially relevant mediating factors.

4.7 | Current trends in innovation research

Finally, several innovation topics appear relevant in relation to strategic leadership. First, digital technological innovation is reshaping entire industries, economies, and societies (Bankewitz, Aberg, & Teuchert, 2016; Nylén & Holmström, 2015). Although this technological discontinuity can destroy incumbent firms' core competencies (Anderson & Tushman, 1990) and drastically alter their strategic contexts (Bankewitz, Aberg, & Teuchert, 2016), it can also be an opportunity (Furr & Shipilov, 2019) if strategic leaders are able to adapt their mental models (Tripsas & Gavetti, 2000) and acquire the necessary resources and competencies (Loucks, Macaulay, Noronha, & Wade, 2016). As digital transformation is now a central theme on strategic leaders' agendas (Warner & Wäger, 2019) and as its consequences are contingent on the capabilities of strategic leaders (Kor & Mesko, 2013), there are numerous research opportunities. For one, scholars might study how strategic leaders react to digital innovations. For instance, researchers could investigate the individual and interactive roles of leaders in the identification, adoption, and management of digital technologies in organizations (Hesse, 2018; Warner & Wäger, 2019) or study how prior experiences and cognitions of strategic leaders, their social ties, and board and TMT configurations foster these processes (Cortellazzo, Bruni, & Zampieri, 2019). For another, digital technologies are likely to result in changes in the composition, ways of working, and cognition of strategic leaders (Bankewitz, Aberg, & Teuchert, 2016).

Second, digitalization may have broader consequences that need to be addressed in the context of corporate governance and strategic leadership. For instance, digital technologies may result in a shift from centralized and hierarchical organizational forms towards more collective forms of decision making characterized by decentralization and disintermediation (Fenwick & Vermeulen, 2019). Scholars might ponder how this requires adaptations of established forms of corporate governance. In this regard, artificial intelligence (AI) requires particular attention. Machines often achieve greater decision quality than humans, especially in complex situations characterized by an abundance of data, such as director selection (Erel, Stern, Chenhao, & Weisbach, 2018; Jarrahi, 2018). Furthermore, companies such as the Finnish software company Tieto have begun to appoint AI “members” to their leadership teams (Tieto, 2016). Although such decisions are met with skepticism and amusement by commentators, they highlight the need to align data-driven decision-making processes with classic models of corporate governance focused on people and accountability (Fenwick & Vermeulen, 2019). Further advances in machine learning (Jarrahi, 2018) also call for research on the possibilities for and consequences of deeper integration of AI as both a governing element and an element to be governed (Raisch & Krakowski, 2020).

Third, sustainability-related business practices are increasingly important for firms (Klewitz & Hansen, 2014). Technological innovation is likely to play a key role in enabling such practices (Fagerberg, 2018), and strategic leadership naturally influences their adoption (Rego, Cunha, & Polónia, 2017). However, we know little about whether and how anchoring sustainability in the TMT or the board affects firms' innovation processes. In particular, sustainable innovation practices require a shift of attention from economic performance towards environmental and social aspects (Wiengarten, Lo, & Lam, 2017). To achieve this shift, boards may need to reconsider CEO and TMT incentives. In this regard, future research can provide guidance on which incentives and performance indicators are most suitable for encouraging sustainable innovation processes and the development of sustainable products and services.

Finally, we see research opportunities in the fields of user innovation and open innovation, both of which differ from traditional, producer-focused innovation (Baldwin & Hippel, 2011). In user innovation, those using products, services, or processes are the source of innovations (Baldwin & Hippel, 2011). Open innovation is a "distributed innovation process that relies on purposively managed knowledge flows across organizational boundaries" (Chesbrough, 2017, p. 35), which includes opening firms' innovation processes to external knowledge sources (Chesbrough, Vanhaverbeke, & West, 2006). Both types of innovation require revisiting established knowledge-management and product- and service-development practices (Baldwin & Hippel, 2011). As such, they force strategic leaders to substantially adapt their mental models and behaviors. This creates a need to study, for example, the relationship between strategic leaders' collaboration activities inside and outside the organization and user and open innovation. Researchers could also analyze how strategic leaders of incumbent firms simultaneously manage traditional and open innovation models to identify the related challenges and examine the types, constellations, and capabilities of strategic leaders that are most beneficial in such contexts (Altman & Tushman, 2017).

5 | PRACTICAL IMPLICATIONS

Our findings also have important implications for practitioners. First, our overview of the relationships between CEO characteristics and innovation outcomes provides board members with guidance for selecting a CEO who can successfully manage innovation given the firm's circumstances. For example, directors should carefully evaluate the potential CEO's educational background (e.g., Barker & Mueller, 2002), prior work experience (e.g., Deeds, DeCarolis, & Coombs, 2000), and other directorships (Oh & Barker, 2018), as these factors can affect the candidate's innovation decisions. In addition, boards need to consider environmental aspects, such as environmental dynamism (Nadkarni & Chen, 2014; Wu, Levitas, & Priem, 2005), as well as organizational aspects, such as the firm's experience with strategic alliances (Tyler & Steensma, 1998), as these factors moderate the relationship between CEO characteristics and innovation outcomes.

Second, the research summarized here provides boards with guidance regarding the use of managerial compensation to motivate the TMT to focus on long-term firm outcomes. Some examples include using stock options to mitigate CEOs' career-horizon issues (Zona, 2016) and focusing on long-term TMT compensation elements to foster innovation (Gopalan, Milbourn, Song, & Thakor, 2014).

Third, as our research comprehensively describes the individual- and group-level effects of board characteristics on technological innovation, it can help shareholders with the challenging task of choosing appropriate directors given the organization's circumstances and the board's current composition. For example, if investors wish to increase the firm's patenting activity, they could consider selecting outside board members with experience in the focal innovation field. Moreover, they may wish to increase the number of directors from ethnic minorities to enhance the firm's innovation output (Cook & Glass, 2015).

6 | LIMITATIONS

Our literature review has several limitations. First, we necessarily focused on a limited set of the most relevant journals. Naturally, there might be additional research on strategic leadership and innovation in other outlets. Second, the results of our review are based on a sample determined by a specific set of keywords. Although we followed an established and systematic process (David & Han, 2004; Rousseau, Manning, & Denyer, 2008) and although the large number of identified studies suggests that we cover a substantial section of the focal topic, the results are limited by the scope of the chosen keywords. Third, we deliberately excluded studies focusing on young firms. Thus, researchers might wish to review the literature dealing with strategic leadership in the context of young firms to examine how this specific context affects the relationship between strategic leaders and innovation. Finally, we focused on technological innovation. Future research could review other forms of innovation, such as administrative, ancillary, or business-model innovation (Damanpour, 1987; Osiyevskyy & Dewald, 2015).

7 | CONCLUSION

In this interdisciplinary review, we aimed to unveil the relationship between strategic leadership and technological innovation. We not only summarized important aspects of this relationship but also stressed the need to extend this line of research. Beyond suggesting that researchers consider a wider range of theoretical approaches, our discussion of potential avenues for future research highlighted the fact that the role of the board of directors in innovation outcomes needs more attention. Moreover, our review reveals a need to better understand the impact of innovation on strategic leadership. Scholars should also exploit novel research settings in order to illuminate additional facets of the relationship between strategic leaders and innovation, and they need to ensure consistency and care in the measurement of innovation. To date, scholarship has led to the accumulation of a broad body of valuable knowledge on the relationship between strategic leadership and innovation. We are optimistic that our review will enable researchers to make even better use of this knowledge and further advance this promising field of research.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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NOTES

[1] Such monitoring activities might also offset the negative relationship between the outsider ratio and R&D investments (Deutsch, 2005). In this regard, Deutsch (2005) cautioned that the relationship between board composition and risk reduction might stem from reverse causality. Firms with CEOs who underinvest in R&D may be in greater need of a vigilant board and, thus, seek a higher share of outside directors. However, this explanation might contradict more recent findings indicating that firms with increasing R&D intensity are more likely to appoint an outside director as the board chairperson, thereby increasing board vigilance (Balsam, Puthenpurackal, & Upadhyay, 2016).

[2] We searched papers for the terms "endogen*," "causal*," "omitted," "selection," "simultaneity," and "common method." We did not search conceptual papers, qualitative papers, and meta-analytic studies.

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