

ORIGINAL ARTICLE OPEN ACCESS

Industry-Specific CEO Experience on Boards and Environmental Innovation

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Received: 26 September 2023 | **Revised:** 8 September 2025 | **Accepted:** 10 September 2025

Funding: The authors received no specific funding for this work.

Keywords: board structure | corporate governance | environmental innovation | firm performance | firm value | independent directors | industry-specific CEO experience

ABSTRACT

Research Question/Issue: This study aims to examine the impact of independent directors' industry-specific CEO experience on environmental innovation and subsequent firm performance and value in US firms.

Research Findings/Insights: Drawing key insights from the management, corporate governance, and innovation literature, this study provides new empirical evidence that independent directors with CEO experience in industries similar to the appointing firm tend to promote value-enhancing environmental innovation strategies. Our findings reveal that while the presence of industry-specific CEO directors on the board may reduce environmental innovation, this reduction aligns with industry norms and contributes to improved firm performance and value. Furthermore, this effect is more pronounced in states with weak environmental regulation, where environmental initiatives are discretionary rather than mandatory. Finally, we ruled out alternative explanations for our results, which remained robust across various specifications and tests.

Theoretical/Academic Implications: We provide robust evidence that independent directors' industry-specific CEO experience affects environmental innovation at the firm level, thus adding and further expanding the literature on the corporate outcomes of the board of directors' human capital. Second, we provide evidence on the impact of environmental innovation initiated by firms with industry-aligned CEO expertise on their boards on firm value and performance. Third, our study answers the current call for research on any neglected individual-level factors that could possibly shape a firm's focus towards environmental innovation. Fourth, our sample period is long enough to capture potential changes in external conditions that may have influenced firm behavior and outcomes. Thus, we go beyond prior studies and control for several factors likely to affect a firm's environmental innovation.

Practitioner/Policy Implications: We demonstrate that independent directors with industry-specific CEO experience contribute to firm profitability and value by guiding firms towards industry-consistent, higher value-added, and performance-enhancing green innovation levels. These results have important implications for corporate decision-making in firm environmental innovation and beyond.

1 | Introduction

Environmental innovation is catalytic to a firm's competitive advantage and legitimacy (Bird et al. 2007; Petrenko et al. 2016;

Watson et al. 2018; Liao et al. 2021; Bezemer et al. 2023; Pandey et al. 2023) and is an important contributor to smart, sustainable, and inclusive growth (OECD 2021; Fabrizi et al. 2018). Almost all definitions of environmental innovation are aligned

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in regard to its outcome; it is a product, a process, a service, or a model that satisfies a user's need or solves a problem and is competitive in the market (Reid and Miedzinski 2008; Tietze et al. 2011; Petrenko et al. 2016; OECD 2021). Regarding its environmental impact, all definitions point to environmentally sustainable outcomes (Andersen 2008; Tietze et al. 2011; Fabrizi et al. 2018).

Given the impact of climate change and other societal grand challenges, environmental innovations are vital for firms to develop legitimacy and mitigate climate change-related issues. Unlike conventional innovation, which is predominantly market-driven—stemming from market competition or technological advancements—environmental innovation is often driven by regulations, sustainability targets, or environmental externalities (Porter and Van der Linde 1995). Its focus on addressing climate change, reducing pollution, and improving efficient use of resources creates challenges that may require the analogous changes in the corporate strategy, no matter whether these changes are the optimal ones for the firm to pursue at a given time (Porter and Van der Linde 1995; Delmas and Montes-Sancho 2011). Furthermore, environmental innovation faces specific barriers, such as high upfront costs and market failures, which make this initiative particularly uncertain and risky for the firm (Horbach 2008). In such a context, understanding the drivers and channels of environmental innovation is becoming increasingly important. In this paper, we zoom in on the important factors that may drive or hinder a firm's environmental innovation—the role of independent directors.

Research conducted on the antecedents of different types of innovations agrees on the fact that the board of directors (BoD) has a catalytic role in inducing or hindering innovation for a firm (Horbach 2008; Jain and Jamali 2016; Bezemer et al. 2023; Hsieh et al. 2022). These studies have largely treated the board's independent directors as a homogeneous group. Furthermore, those that did acknowledge the heterogeneity found among directors in regard to firm innovation mainly focused on their demographical differences—for example, age, education, gender, race, and ethnicity—and have remained silent in relation to the human capital traits that individual directors bring to the board (Byron and Post 2016; Briano-Turrent 2022; Zaman et al. 2023). A handful of studies have given a more nuanced view on the attributes of independent directors, looking, for example, at long-tenured directors (Bonini et al. 2022), at the extent by which some boards are now too independent (Zorn et al. 2017), or at the appointments of lead independent directors. Yet, they have examined these attributes in the context of more generic performance consequences.

In this study, we focused on the role of board independent directors with CEO experience within the same industry as the focal firm. Specifically, our study sought to determine whether such industry-aligned CEO expertise influences environmental innovation, as measured by green patents, and whether this effect serves as a channel through which industry-CEO expert directors affect firm value and performance. Unlike previous studies that focused on general industry expertise among board members (e.g., Kroll et al. 2008; Tian et al. 2011; Balsmeier et al. 2014; Drobetz et al. 2018), we specifically target

independent directors with CEO-level experience in firms operating within the same industry as the focal company. This focus is critical because CEOs are the primary architects of corporate strategy and the ones highly impacting decision-making, dealing with complex environmental challenges and determining performance. We aim to capture the influence of the decision-makers whose familiarity with industry dynamics includes ultimate responsibility for the execution of strategic, financial, and operational decisions. For this reason, we direct our attention to the strategic implications of industry-aligned strategic leadership and its effect on both environmental innovation and firm value.

We deemed this area deserving of greater attention for at least three reasons. First, in the rather limited literature that exists in the industry-specific CEO experience, it has been shown that CEO experience obtained in the same industry is a vital source of human capital (Kang et al. 2018). In these discussions, academics have stressed the growing importance of experiential capital on a board's ability to source information, as well as its ability to provide effective oversight and advisory support to executive leadership on strategic firm-level matters (Kor and Sundaramurthy 2009; Drobetz et al. 2018; Zhang et al. 2025). Second, although past research acknowledges the value of industry-relevant experience and CEO experience on corporate boards, the conditions, interrelations, and underlying mechanisms through which this experience contributes to board effectiveness need further clarification. Third, notwithstanding the increased regulatory pressures as well as its relevance in CEOs' agendas, we deem the examination of environmental innovation individually and in separation from a firm's total innovation essential, since, as noted above, the motives behind environment-related initiatives of firms are not clearly identified in the relevant literature (Carrión-Flores and Innes 2010; Barbieri et al. 2017).

In this paper, we argued that while the presence of directors with industry-specific CEO experience may negatively affect environmental innovation, it can still contribute to enhancing the firm's overall value. Drawing on green patent data covering the 2001–2021 period, our results evinced that boards with independent directors possessing current or past CEO experience within the same industry are more likely to generate less environmental innovation. Notably, however, this reduction does not translate into negative firm outcomes. On the contrary, it is found to enhance firm performance and, on average, stocks of firms with boards with greater industry-aligned CEO expertise seem to be highly valued by the stock market.

To our knowledge, our study is the first to examine the impact of independent directors' industry-specific CEO experience on environmental innovation and on subsequent firm performance and value. Furthermore, this study differentiates itself from previous research on board attributes and environmental innovation by specifically examining these innovations through the lens of green patents. Accordingly, our results contribute to the literature on environmental innovation in the following ways. First, we provide robust evidence that directors' industry-specific CEO experience affects environmental innovation at the firm level, thus adding to and further expanding the literature on the corporate outcomes of BoD

characteristics (Amin et al. 2020; Lee 2020; Lim et al. 2020). Second, we expand the very few findings that exist in this research stream by providing new evidence on the impact of environmental innovation on firm performance and value. Third, our study answers the current call for research on any neglected individual-level factors that could possibly shape a company's focus towards environmental innovation (Arena et al. 2018; Kang et al. 2018). Fourth, our sample period (2001–2021) was long enough to capture potential changes in external conditions that may have influenced firm behavior and outcomes. Thus, we went beyond prior studies and controlled for several factors likely to affect a firm's environmental innovation, thereby minimizing the risk of potential omitted variables bias. Lastly, the findings of our study are based on large-sample evidence obtained using corporate-level environmental innovation outcome measures based on archival patent data; conversely, most prior firm-level studies (e.g., Eiadat et al. 2008; Kunapatarawong and Martínez-Ros 2016; Arena et al. 2018; Konadu et al. 2020) provided small-sample evidence or innovation measures based on surveys. Lastly, we utilize multiple identification strategies to demonstrate that endogenous factors are unlikely to influence our conclusions or inferences. We also perform a range of tests to validate the robustness of our results.

The rest of the paper is structured as follows. Next, we provide an overview of the key findings in the existing and related literature and develop our hypotheses. Then, we describe our data and variables, and we continue by discussing our empirical methodology and results. In the subsequent sections, we discuss our robustness checks, measures to check for endogeneity issues, and further analysis. In Section 5, we provide a conclusion for the study.

2 | Related Literature

2.1 | Independent Directors With Industry-Specific CEO Experience

A growing stream of research highlights the advisory skills of independent directors with experience in similar industries as the appointing firm, stressing that these directors contribute unique insights, expertise, and difficult-to-obtain information. With their industry-specific experience, they play an important role in advising on key firm decisions, especially when it comes to firms with complex operations (Adams and Ferreira 2007; Linck et al. 2008; Boone et al. 2007; Kor and Sundaramurthy 2009; Coles et al. 2008, 2014). Moreover, directors with industry-specific experience have been found to be positively associated with a firm's sales growth and firm performance, fewer earnings restatements, and larger cash holdings (Kor and Sundaramurthy 2009). In the innovation literature, independent directors in similar industries or technological areas as the appointing firm were found to increase innovations as proxied by the number of patent applications, citations, or R&D investment (Balsmeier et al. 2014; Chen 2014; Faleye et al. 2018). This indicates that directors with the appropriate professional background constitute a source of information transfer, bringing specific expertise to the boardroom. Further evidence in the area also posits that industry-experienced

directors are possibly better monitors because their specialized expertise allows them to comprehend the challenges or the opportunities evident in the environment of the firm, to efficiently scrutinize information relevant to the operational or financial performance of the firm, and to assess the effectiveness of the managerial decision-making (Wang et al. 2015). Carpenter and Westphal (2001) found that these directors effectively monitor and contribute to strategic decision-making, especially if appointed from similar strategic product and geographic markets. Research has also pointed to risks associated with having same industry experts on the board. One downside of such a regime could relate to the ties these directors share with top management due to the common professional and perhaps social circles, or even career crossings. This may compromise the effectiveness of monitoring and diminish the power of these directors, while it can open windows to self-serving behavior (Wang et al. 2015).

Complementing this literature is a growing body of research on independent directors with CEO experience, whose role on boards, particularly as former or current CEOs, has been somewhat highlighted in the literature of board human capital. In this context, the effects of CEOs acting as independent directors remain rather scarce and inconclusive. Fahlenbrach et al. (2010) identified that external board memberships for CEOs provide a personal advantage to such directors, rather than to the firm itself. The argument behind such reasoning lies in the popularity of former or current CEO directors, who get to pick those boards that provide them with optimal compensation packages in relation to the effort and risk linked to their service and to the networking opportunities associated with the role. Moreover, the need for these directors significantly weakens in the presence of a high-quality institutional environment (Oehmichen et al. 2017) and in more dynamic industries (Drobetz et al. 2018). Fich (2005) linked announcements of former or current CEOs being appointed as independent directors to abnormal positive stock returns and the aftermath of such appointments to record improvements in operating performance. Also, Tian et al. (2011) found a positive relationship between independent board members' CEO experience and investor reactions to a new CEO appointment. Furthermore, Platt and Platt (2012) found higher proportions of former or current CEOs on the boards of nonbankrupt firms, as opposed to bankrupt ones, and Li and Qian (2011) documented an increase in CEO compensation in the presence of at least one former or current CEO outside director serving on the compensation committee. Wang and Dewhirst (1992) found that former or current CEO independent directors tend to be more cautious as far as governmental compliance is concerned, while Stevenson and Radin (2009) did not record any difference between the influence exerted on a firm by former or current CEO directors and that wielded by other board members.

While the literature on independent directors with industry-specific experience and that on those with CEO experience has evolved in parallel, the two streams suggest different but potentially complementary dynamics to board effectiveness. Directors with industry-specific expertise are a reservoir of resources and providers of knowledge and operational insight, offering valuable advice on matters that are endemic to each

industry. Independent directors with CEO experience bring advanced strategic and governance capabilities, strategic relevance, and effective monitoring (Tian et al. 2011) as well as a unique way to communicate with the focal firm's CEO in ways that fall outside the purview of typical independent directors. Only a few studies directly examine the intersection of these two characteristics. For example, Kang et al. (2018) identified CEO–industry experience as a channel through which directors contribute to value-added R&D activities, suggesting that such confluence may enhance firm innovation and long-term growth.

2.2 | Independent Directors and Environmental Innovation

Studies in the current literature seem to focus on those attributes of independent directors that are linked to the likelihood of a firm to commit to sustainability initiatives in the broader context of corporate social responsibility (CSR) rather than specifically on environmental innovation. For instance, in the context of CSR, these studies have investigated the effects of board diversity (e.g., Harjoto et al. 2015; Liu 2018; Atif et al. 2020), board independence (e.g., Zhang et al. 2013; Chang et al. 2017), board connectedness (e.g., Chang et al. 2017), and board reforms (Liao et al. 2021). In the context of ESG, studies found that labor board representatives prioritize social performance at the expense of environmental and governance performance (Nekhili et al. 2021). Arena et al. (2024) show that demographic fault lines within boards impede their ability to process information effectively, thereby limiting the adoption of proactive environmental strategies. Thus, a specific focus on environmental innovation as an outcome of these firm attributes has been largely disregarded.

The rather limited number of studies that have attempted to investigate the relation between board structure and environmental innovation has been centered on board gender diversity and on certain moderating relationships that hinder or promote this type of innovation. In particular, boards with larger proportions of female directors (Terjesen et al. 2009; He and Jiang 2019; Nadeem et al. 2020; García-Sánchez et al. 2021; Moreno-Ureba et al. 2022; Moran-Muñoz et al. 2025) have been associated with a greater degree of socially responsible and environmental innovation activities. Moreover, the external social capital brought by female directors has been shown to contribute to their capacity to promote innovation in sustainable practices (Glass et al. 2016). In a different strand of literature, Usman et al. (2020) drew on board internationalization and found that the presence of foreign directors on the board intensifies green business practices. Regarding the moderating attributes examined in the literature, García-Sánchez (2020) posited that managers exhibit a minimal commitment to environmental issues when the company is operating in munificent and dynamic environments and suggested that in such cases, only a strong internal corporate governance system can promote environmentalism. Public and private shareholder activism as a moderating variable was associated with community or external reporting issues, as it strengthens the positive influence of independent directors on firms' environmental innovations (Ruiz-Castillo et al. 2024).

2.3 | Hypothesis Development

2.3.1 | Industry-Specific CEO Experience and Environmental Innovation

Independent directors may have several work experiences. A collection of different experiences within an individual director may generate a profile of a director that is particularly valuable for a firm's board. For this reason, studies underscore the advisory capacity industry experts possess because of industry-specific knowledge, information, and first-hand experience they bring to board discussions (e.g., Balsmeier et al. 2014; Griffin et al. 2021). According to resource dependence theory, these directors are viewed as a pool of resources and a channel for information, bringing specific knowledge and experience that become particularly useful when companies are characterized by complex operations (Haynes and Hillman 2010; Faleye et al. 2013; Coles et al. 2014; Diestre et al. 2015). The benefits of industry experience become even more evident at the CEO level (Kang et al. 2018). CEOs are the most demanded outside directors due to their first-hand experience with strategic leadership (Mutlu et al. 2021; Croci et al. 2024). Their experience provides general knowledge of how to strategically manage a firm, since they are the key players in making final decisions on all key operational and strategic issues. When this general knowledge is combined with industry-specific knowledge, it enhances directors' capabilities that will help the implementation of industry-specific strategies, which will lead to higher firm value. The knowledge they possess about how businesses are managed, their expertise in judging and estimating product or service demands while ensuring compliance with industry-related regulatory standards and while considering the industry's competition, as well as their ability to ensure best practices for all stakeholders are unique contributions they can bring to the boardroom (Kor and Misangyi 2008; Oehmichen et al. 2017). Additionally, these directors hold uncommon expertise and have a unique way of facing and communicating with the CEO as peers. They can become particularly valuable in this context due to their unique ability to provide guidance and oversight to the CEO that goes beyond the conventional oversight role of independent directors (Rajagopalan and Spreitzer 1997). Given these arguments, we identify two distinct pathways through which industry-specific CEO experience can affect a firm's environmental innovation, which is endemic to each industry.

On one hand, it is likely that firms which appoint industry-specific CEO experts on their boards gain certification advantages over other firms because such appointments show that leaders whose human capital depends on reputation appreciate them enough to join them (Faleye et al. 2018). Bilaterally, when these directors join a board, they need to reaffirm that their reputation and human capital will be protected. Faleye et al. (2018), for example, found that industry experts on the board reduce R&D-based real earnings management and contribute to value-enhancing R&D investments. The rationale behind this is that, compared to other independent directors, CEOs who are also native to the industry would pay a high price for any association with firms exhibiting poor performance. Not only would their success in the labor market

be at risk (Fich and Shivdasani 2007), their current authority and perceived competence in the firms they lead would also be also tarnished. This is also exhibited in Fahlenbrach et al. (2010), who showed that CEO directors are less likely to join boards of younger, smaller, and nondividend-paying firms. Therefore, the decision to join a board as an independent director entails increased responsibility, as it involves contributing to high-quality advising and monitoring while, at the same time, safeguarding one's reputation. This reputational concern may be a reason for these directors to promote environmentally responsible corporate acts, which constitute a visible and stakeholder-valued practice, therefore enhancing environmental innovation performance.

Hypothesis 1a. *Industry-specific CEO experience among a board's independent directors is positively related to the firm's environmental innovation performance.*

However, their familiarity with industry norms (derived from their industry-related expertise) as well as efficiency- and profitability-enhancing strategies (derived from their CEO-related expertise) may instead make them less susceptible to these types of investments due to the troublesome and too experimental nature for producing short-term results. Given that environmental innovation is a new, risky, and complex strategy that takes time to recoup initial investment costs (Porter and Van der Linde 1995; Delmas and Montes-Sancho 2011; Saeed et al. 2025; Zhang et al. 2025), industry-specific CEO experts may deem other investments more valuable and quicker to borne profits than environmental innovation. Being aware that environmental innovations often go beyond the limits of industry norms, these directors may be in a better position to weigh the benefits of being environmentally compliant to regulatory or stakeholder pressures to the associated costs (Porter and Van der Linde 1995; Delmas and Montes-Sancho 2011). Moreover, environmental innovation investments, involve heightened discretion and uncertainty (Horbach 2008). In such a context, industry-specific CEO experts with the provision of their organizational capital (insights into processes suited for organizing complex activities and for supporting the evaluation, selection, and implementation of investment projects) may emphasize on aspects like cost control and immediate financial performance. These aspects contradict entirely the nature of environmental innovations, which often involve upfront costs and long-term returns on the investment and greater risk; if this is indeed the case, a decline in environmental innovation performance would be expected.

Hypothesis 1b. *Industry-specific CEO experience among a board's independent directors is negatively related to the firm's environmental innovation performance.*

To sum up the above arguments, on one hand, the need of these directors to protect and preserve their reputation in their native industry, combined with their ability to competently support and oversee environmental strategies, may increase environmental innovation performance; on the other, their emphasis on efficiency, short-term returns, and rationalization of such investments may constrain environmental innovation. Thus, the direction of the relationship remains uncertain.

2.3.2 | Industry-Specific CEO Experience and Firm Performance

In a similar line of thinking, we do understand that director industry-specific CEO experience has the capability to impact the board's operations. Like our arguments regarding its impact on environmental performance, whether and how industry-specific CEO experience can affect firm performance and value is hard to predict a priori. On one hand, industry-specific CEO directors may exert a high degree of influence in the boardroom and, due to their authority and unique experience, may act as ideal monitors, particularly in preventing any opportunistic rent-seeking actions taken by the incumbent CEO. In this context, while many scholars have traditionally supported an either/or approach to the resource dependence and agency theories in explaining independent director roles, a rapidly expanding body of research is combining both theories to offer a more holistic view of boards (Oehmichen et al. 2017). This idea suggests that industry-specific CEO-experienced boards may excel at resource provision and advising, as well as monitoring (Hillman and Dalziel 2003). Thus, given the risky nature of environmental innovation, the appointing firm's CEO may be prone to avoid worthy but risky investments and decide upon safer ones, regardless of whether these are not optimal for the firm and its value. Because of their exclusive experience, these directors can be expected to have a thorough understanding of risk exposure and of the attitude toward risk held by the firm's incumbent CEO. Thus, they should be able to activate control mechanisms or compensation schemes aimed at incentivizing the CEO to assume the appropriate risk, which would ensure that CEOs will choose those environmental innovation initiatives that are profitable to the firm and enhance its value by being well-aligned to the interests of the shareholders. In this way, the presence of industry-specific CEO experience on the board ensures that valuable investments are made and, at the same time, safeguards the legitimacy of the firm in pursuing socially responsible acts in response to the monitoring of the wider stakeholder base and society at large.

We then posit that the greater level of performance of environmental innovation found in firms with industry-specific CEO experience on the board may be a channel through which the board enhances firm performance and value-added growth.

Hypothesis 2a. *The environmental innovation performance of firms, the boards of which are endowed with industry-specific CEO experience, is positively related to firm profitability.*

Hypothesis 3a. *The environmental innovation performance of firms, the boards of which are endowed with industry-specific CEO experience, is positively related to firm value.*

On the other hand, given the greater pressures exerted by various stakeholders concerned with corporate environmental issues and the prevalent social and legal expectations on environmental commitment, it is possible that these directors have as their sole objective to portray the corporation as environmentally responsible, independent of whether this has a long-term impact on firm performance and value. For example, because of their comprehensive understanding of the industry

and stakeholders' pressures on environmental compliance, these directors may tend to overemphasize such investments, directing the firm's activities away from the optimally, risky strategies that many shareholders prefer. At the same time, their dual role makes these experts overinvested in the firms and boards they run; thus, having increased pressure to sustain their reputation and human capital, realizing that they would pay a high price for any association with firms exhibiting poor environmental practices and compliance. This may induce them to prioritize environmental actions over other, more conventional and less visible actions in the market. Li and Wu (2020) find that public firms engage in environmental, social, and governance (ESG) actions with no real impact on the firm, supporting that shareholder and stakeholder conflicts of interest are the central moderators of decoupled actions between ESG activities and firm value. This is consistent with the notion that only doing good in terms of environmental performance does not necessarily mean that firms do well (Li and Wu 2020). Thus, while their industry-specific CEO expertise may deem them as good advisors and monitors on matters pertaining environmental innovations, if this is done in a sub-optimal way at the expense of other, more valuable positive present-value projects, it could ultimately harm the firm's performance and value.

We may, therefore, expect that the greater level of performance of environmental innovation found in firms with industry-specific CEO experience on the board may be a channel through which the board destroys firm performance and value-added growth.

Hypothesis 2b. *The environmental innovation performance of firms, the boards of which are endowed with industry-specific CEO experience, is negatively related to firm profitability.*

Hypothesis 3b. *The environmental innovation performance of firms, the boards of which are endowed with industry-specific CEO, is negatively related to firm value.*

3 | Data, Sample, and Methodology

3.1 | Data Sources and Sample

For our analysis, we leveraged data from four different data sets: We obtained board variables from BoardEx, CEO variables from Execucomp, financial data from Compustat, and innovation data from the United States Patent and Trademark Office (USPTO)—particularly from the U.S. Patent Application Publication. First, board data from BoardEx, including firm-year observations over the period 2001–2021, were merged with CEO data from Execucomp and financial data from Compustat. The sample period begins in 2001 to ensure consistent and comprehensive coverage of board characteristics provided by BoardEx.

Second, green innovation data were identified and collected from USPTO. In particular, following the Patent Assignment Dataset Schema, detailed information for each assignee (including company name and address) was first assigned to innovation data (patents and forward citations, invention title, application and granted date) and then to the U.S. Patent Application

Publication dataset, which provided a detailed classification of the data. For our analysis, we considered innovation data based on the Cooperative Patent Classification (CPC), and particularly those patents that were classified under the “technologies or applications for mitigation or adaptation against climate change” scheme, which is aligned with the framework of the Kyoto Protocol and the Paris Agreement.

Third, green innovation data from USPTO were merged with the intersection of the BoardEx-Execucomp-Compustat dataset. In particular, following the literature (Bena et al. 2017; Graham et al. 2018), we utilized fuzzy-string matching techniques to create links between the innovation assignee strings extracted from the USPTO and the firms' name strings extracted from Compustat, BoardEx, and Execucomp using the maximum likelihood n-gram approach described in detail by Norvig (2009). In line with prior research, we exclude firms that have never filed a single patent with the USPTO (Jia and Tian 2018). The final merged firm dataset was also verified using the global company key provided by the Global Corporate Patent Dataset (Bena et al. 2017).

Our final sample consisted of 7742 firm-year observations and 565 unique firms over the period 2001–2021. To ensure that our results were not influenced by outliers, we winsorized the continuous variables at the 1st and 99th percentiles.

3.2 | Variable Description

Our main variable of interest was independent director CEO experience in the same industry as the appointing firm, *INDCEODir*, which is defined as the number of independent directors who had current or past work experience as CEOs in the same industry (as reported in BoardEx), divided by the total number of the board's independent directors.

With regard to our dependent variables, in line with recent innovation literature (Hirshleifer et al. 2013; Cho et al. 2016; Aghion and Jaravel 2015; Jiang and Chen 2018; Jiang and Yuan 2018; Li et al. 2020), we proxied environmental innovation, *GreenApplications*, by using the natural logarithm of the number of green filed patents that eventually got granted +1 ($\ln(\text{Patent} + 1)$). Successfully filed patents were chosen to be examined because the date of filing better reflects the actual timing of innovation. The +1 treatment was effected to avoid losing observations with zero filed patents (Lu and Wang). Furthermore, any filed patent observed at time *t* is the result of past independent director initiatives. To address this issue, we employed a 1-year lag for director industry-specific CEO experience for all model specifications testing Hypotheses 1a and 1b. In the valuation models of Hypotheses 2a and 2b and 3a and 3b, environmental innovation was represented by the natural logarithm of the number of green-granted patents +1, *GreenGranted*, because we were interested in capturing the performance and valuation effect of the obtained patents, those that have been established and communicated as successful in the market. Following Kang et al. (2018), we employed up to a 3-year lag, since the valuation effects of granted patents are expected to be reflected on value at later stages. These lag lengths were also confirmed by performing a

series of misspecification tests aimed at addressing any cross-sectional dependence/contemporaneous and serial correlation (Pesaran 2015; Ertur and Musolesi 2017).

To proxy for firm profitability and firm value, we employed Return on Assets (ROA) and Tobin's Q, respectively. ROA was measured as the natural logarithm of the book value of assets for the firm, and Tobin's Q as the market value of common equity plus the book value of assets minus total stockholders' equity and deferred taxes, divided by the book value of total assets.

We controlled for various CEO-, board-, and firm-specific variables that we expected would affect the relationship between director industry-specific CEO experience and environmental innovation, as well as for the interactive effects of these two latter variables on firm profitability and value. With regard to CEO-level controls, we included industry, *IndDir*, and CEO experience of independent directors on the board, *CEODir*, to ensure that our results were not driven by the industry or managerial experience of independent directors, respectively (Kang et al. 2018); *CEOTenure*, to control for the firms' CEO risk-taking tendencies (Simsek 2007; Brookman and Thistle 2009), thus their attitudes towards innovative activities; CEO duality, *CEODual*, to account for CEO formal power (McNulty et al. 2013; Aktas et al. 2019). We also looked at CEO *Salary*, *Bonus*, option incentives, *OptionInc*, and stock incentives, *StockInc*, as possible compensation mechanisms aimed at incentivizing the CEO to decide upon investments that could benefit the firms' shareholders (Bergstresser and Philippon 2006; Conyon and He 2012). Furthermore, acknowledging that different board dynamics affect the firm outcomes, we controlled for board size, *BSize*, to reflect the effects of larger boards on firm value and performance (Dalton et al. 1999; McNulty et al. 2013); and board independence, *Indep*, to proxy for superior board monitoring and control activities (Johnson et al. 2013; Schiehl et al. 2023); female directors, *FemDir*, since past research has revealed a positive effect of female independent directors on CSR and eco-friendly firm outcomes (He and Jiang 2019; Nadeem et al. 2020; García-Sánchez et al. 2021; Moreno-Ureba et al. 2022); educational diversity, *EduDiversity*, to ensure that the effect of our independent variable on environmental innovation does not stem from the educational background of directors (Cumming and Leung 2021; Hsieh et al. 2022); board network, *NetworkSize*, to ensure that our results are not driven by well-connected boards (Chang and Wu 2021) or committees, as illustrated in Edacherian et al. (2024). Finally, we controlled for the observable firm characteristics that have been found in the literature to affect innovation activities. These are R&D expenditures, *R&DExp*, as a key input of the patent initiation process (Chen 2008; Lu and Wang 2018); Capital expenditures, *CapitalExp*, to gauge the capital intensity of the firm (Nadeem et al. 2020); *Leverage*, to proxy for firm riskiness (Chen 2008; Lu and Wang 2018); firm size, *Size*, to control for potential economies of scale in patenting (Cho et al. 2016); industry competition, *HHI*, to ensure that the effect on environmental innovation is not driven by high product market industry competition (Kang et al. 2018); asset tangibility, *AssetTang*, to control for organizational complexity (Kang et al. 2018); and *logTotalApplications* to steer clear of the possibility that green innovation is simply capturing the overall innovation quality of the firm. We employed year-fixed effects and industry-fixed effects. For the industry-fixed effects—by using

Fama and French's (1997) industry classification—to control for any unobserved inter-industry differences.

3.3 | Descriptive Statistics and Correlations

Panel A of Table 1 reports the descriptive statistics for the variables used in the analysis. The mean value of *GreenApplications* was found to be 0.67, showing that our sample firms had, on average, one green patent application per year.

Around 11% of firms in our sample have boards with industry-specific CEO independent directors, *INDCEODir*. This proportion is somewhat higher than figures reported in earlier studies such as Kang et al. (2018), whose sample period ended in 2010. What is obvious in our sample is a steadily increasing preference through the years for these types of directors joining boards. Similarly, 44% of independent directors in our sample have prior CEO experience, reflecting an ongoing trend toward greater representation of executives on boards. Together, these patterns suggest that firms are increasingly prioritizing executive and industry-specific expertise in board composition. Industry experience appears to be more common in our sample; on average, 92% of the independent directors on each board appear to hold industry-specific experience. This widespread presence is also evident in Kang et al. (2018), reinforcing the idea that such experience is quite common in board composition. Our sample CEOs, on average, were found to have a mean tenure of around 8 years in the firms they served, and those who had held the position of chair were found in 52% of the sample firm-years. These figures are similar to past research (e.g., Aktas et al. 2019). Regarding the variables to measure CEOs' incentives to promote green innovation, the average CEO salary to total compensation is 0.223, and bonus to total compensation is 0.061. CEO option incentive ratio is equal to 0.217, while stock incentive ratio is equal to 0.188. The mean firm in our sample was found to have boards of around nine members, 79% of whom were independent, 14% female, with 49% educational diversity, and with an average network of around eight overlaps through employment, other activities, and education. With respect to firm-level characteristics, similarly to previous studies (Wang et al. 2015; Kang et al. 2018), the mean firm in our sample has an average ROA of 0.084, a Tobin's Q of 5.506, an R&D ratio of 0.155, a capital expenditure ratio of 0.053, and a leverage ratio of 0.21. Moreover, alike Kang et al. (2018), firm size is 7.939, and the asset tangibility of mean firms in the sample is around 0.19.

Panel B of Table 1 exhibited the distribution of the sample by industry. The highest number of observations is found in the industries of business equipment and manufacturing, while the highest number of green applications is found in the industry of telecommunications, and the lowest number is found in shops.

From Panel C of Table 1, which reports the Pearson correlation matrix of these variables, we can see that the Pearson correlations between *GreenApplications* and *INDCEODir* were found to be -0.115 , significant at the 1% level. This initial pairwise correlation designated a negative relation between independent director industry-specific CEO experience and environmental innovation. We additionally observed that our sample firms with independent director industry-specific CEO experience

TABLE 1 | Descriptive statistics and correlations.

Panel A					
Variable	Mean	Std. dev.	Q1	Median	Q3
<i>GreenApplications</i>	0.670	1.068	0.000	0.000	1.099
<i>INDCEODir</i>	0.114	0.136	0.000	0.095	0.167
<i>IndDir</i>	0.922	0.183	0.818	0.917	1.000
<i>CEODir</i>	0.444	0.206	0.300	0.444	0.600
<i>CEOTenure</i>	7.631	6.909	2.752	5.582	9.999
<i>CEODual</i>	0.518	0.500	0.000	1.000	1.000
<i>Salary</i>	0.223	0.200	0.100	0.155	0.265
<i>Bonus</i>	0.061	0.122	0.000	0.000	0.067
<i>OptionInc</i>	0.217	0.199	0.061	0.167	0.321
<i>StockInc</i>	0.188	0.230	0.041	0.103	0.227
<i>BSize</i>	8.760	2.719	7.000	9.000	11.000
<i>Indep</i>	0.787	0.134	0.727	0.818	0.889
<i>FemDir</i>	0.136	0.109	0.000	0.133	0.200
<i>EduDiversity</i>	0.490	0.176	0.367	0.472	0.594
<i>NetworkSize</i>	7.576	0.643	7.183	7.621	8.042
<i>R&DExp</i>	0.155	0.898	0.018	0.049	0.144
<i>CapitalExp</i>	0.053	0.074	0.023	0.036	0.057
<i>Leverage</i>	0.212	0.181	0.050	0.199	0.315
<i>Size</i>	7.939	1.759	6.688	7.830	9.063
<i>HHI</i>	0.131	0.133	0.064	0.100	0.131
<i>AssetTang</i>	0.193	0.142	0.089	0.155	0.264
<i>Lag TotalApplications</i>	2.811	1.929	1.386	2.833	4.111
<i>ROA</i>	0.084	0.109	0.049	0.092	0.136
<i>Tobins' Q</i>	5.506	9.316	2.745	3.994	6.403

TABLE 1 | (Continued)

Panel B											
Industry	N	Mean	Std. dev.								
Consumer NonDurables	280	0.289	0.697								
Consumer Durables	540	0.767	1.111								
Manufacturing	1780	0.653	1.087								
Energy	168	1.430	1.394								
Chemicals	564	0.473	0.770								
Business Equipment	2986	0.767	1.142								
Telecommunication	31	1.506	1.437								
Shops	211	0.272	0.711								
Health	1009	0.469	0.746								
Other	173	0.891	1.424								
Total	7742	0.670	1.068								
Panel C											
Variables	GreenApplications	INDCEODir	RnDExp	CapitalExp	Leverage	Size	HHI	AssetTang	Lag TotalApplications	ROA	Tobin's Q
GreenApplications	1.000										
INDCEODir	−0.115***	1.000									
RnDExp	−0.027**	0.152***	1.000								
CapitalExp	0.074***	0.046***	0.376***	1.000							
Leverage	−0.004	−0.076***	0.023**	0.010	1.000						
Size	0.437***	−0.178***	−0.125***	−0.002	0.291***	1.000					
HHI	−0.042***	−0.098***	−0.059***	−0.090***	0.099***	0.137***	1.000				
AssetTang	0.054***	−0.143***	−0.110***	0.298***	0.156***	0.171***	0.040***	1.000			
Lag	0.662***	−0.040***	−0.019*	0.053***	0.007	0.520***	−0.063***	−0.066***	1.000		
TotalApplications											
ROA	0.071***	−0.122***	−0.334***	−0.243***	−0.016	0.292***	0.073***	0.081***	0.124***	1.000	
Tobin's Q	0.047***	−0.009	−0.013	0.009	0.130***	0.137***	0.042***	−0.008	0.072***	0.113***	1.000

Note: This table reports descriptive statistics for the variables in Panel A, total green patent applications by each Fama and French's 12 industries in Panel B, and the correlation matrix in Panel C. Our final sample consists of 7742 firm-year observations over the 2001–2021 period. Panel C reports the Pearson correlation matrix. All variables are defined in Appendix A. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

were smaller in size and had lower profitability (as indicated by ROA).

4 | Empirical Methodology and Results

4.1 | Independent Director Industry-Specific CEO Experience and Green Innovation

To examine the relation between independent director industry-specific CEO experience and environmental innovation, we employed the following baseline empirical model,

$$\begin{aligned} EnvInnov_{i,t} = & \alpha_i + \beta_1 INDCEDir_{i,t-1} + \beta_2 R\&DExp_{i,t-1} + \beta_3 CapitalExp_{i,t-1} + \beta_4 Leverage_{i,t-1} \\ & + \beta_5 Size_{i,t-1} + \beta_6 HHI_{i,t-1} + \beta_7 AssetTangibility_{i,t-1} + \beta_8 TotalInnov_{i,t} \\ & + \sum Industry_t^i + \sum year_t^i + e_{it} \end{aligned} \quad (1)$$

The dependent variable representing environmental innovation defined in Section 3.2 reflects the patent filings of granted patents of firm i in year t , where the set of the regressors included the main independent variable, independent director industry-specific CEO experience, along with the additional controls, all described in Section 3.2 and in Appendix A.

Following the literature (Gouriéroux et al. 1984a, 1984b; Hausman et al. 1984; Wooldridge 1997; Wooldridge 2002), Equation (1) was estimated using a Poisson Maximum Likelihood Regression—a standard approach to model panel count data that presents significant advantages compared to typical linear regression. In particular, the Poisson regression is appropriate for dependent variables with nonnegative values without any inferences about the distribution. In addition, in the presence of heteroscedasticity, particularly for log-linearized models, the OLS will estimate inconsistent parameters as opposed to the Poisson Maximum Likelihood Regression (Griliches 1984; Correia et al. 2019). Further, to ensure the statistical adequacy of our model, we implemented a series of misspecification tests, including the Breusch-Pagan Lagrange multiplier and the Pesaran (2015) test for cross-sectional dependence/contemporaneous correlation, a Wald test for heteroscedasticity, serial correlation tests, unit root tests for stationarity, and the RESET test regarding the functional form, which uncovered the presence of a linear model. We employed robust cluster standard errors adjusted for firm-level clustering to control for time series correlations in the standard errors and heteroscedasticity in the data (Petersen 2009; Shoham et al. 2020).

Table 2, Model 1, shows the results with coefficients and robust standard errors of the Poisson Maximum Likelihood Regression considering the innovation measure of filed green-granted patents (Model 1).

The results highlighted a negative and statistically significant (at the 1% level) relation between independent director industry-specific CEO experience and green patents. These findings provided support for our first (Hypothesis 1b) hypothesis that the presence of industry-specific CEO experience among the board's outsiders leads to a reduction of green innovation. Given their rigorous monitoring as well as the

knowledgeable consultation, these directors might rationalize green innovation as being less of a priority, perhaps because green initiatives may be less aligned with immediate financial returns or established strategies. Therefore, given also the greater cost involved with such investments, these firms might decide to reduce green innovation to undertake alternative, less transformative investments. In regard to firm control variables, similarly to Lu and Wang (2018), *AssetTang* seems to keep a positive sign for environmental innovation, verifying that substantial physical assets can often be the reason for a firm to face higher regulatory pressures for green innovations, but at the same time a cause for firms to secure more

financing for such capital-intensive innovations. As expected, the total firm innovations are significantly and positively related to green innovations, confirming that firms with higher overall innovation performance also tend to invest more in environmental innovations. All other firm-level control variables did not exhibit a significant relation to environmental innovation.

In Models 2 and 3 of Table 2, we expand the baseline model to include a range of CEO- and Board-level controls, respectively. These variables have been proved in previous literature to affect firm policies. If the negative effect of director industry-specific CEO experience on environmental innovation is due to CEO traits or governance structures, then we would expect this effect to diminish when these controls are included in the model. In Model 2, whereby the CEO-level variables are added, the negative relation between industry-specific CEO experience persists at the 1% level of significance. For the control variables, among CEO characteristics, *CEOTenure* showed a tendency to reduce environmental innovation, which may mean that longer-tenured CEOs tend to exhibit risk avoidance and aversion (Simsek 2007), avoiding costly and uncertain projects such as environmental innovation initiatives. *CEODual* seemed to enhance innovation quality, verifying prior research suggesting that the effects of CEO duality vary based on the environment the company is operating in. Given the complexity and dynamism of the innovative firm environment, it seems that the dual regime under such an environment is beneficial (Boyd 1995). CEO salary, *Salary*, reduced environmental innovation, consistent with the notion that salary itself cannot suffice to incentivize risk-averse CEOs to undertake risky activities. On the contrary, *Bonus* seemed to promote such innovations, showing that the provision of additional financial rewards linked to environmentally friendly acts is aligned with greater environmental activities. Lastly, regarding option compensation incentives, *OptionInc* versus stock compensation, *StockInc*, it seems that stock compensation is the appropriate mechanism to incentivize CEOs toward undertaking more environmental innovation initiatives.

In Model 3, when board-level variables are included in the model, in addition to CEO variables, the strongly significant at the 1% level relation of our independent variable to environmental innovation still survived. In particular, board independence,

TABLE 2 | Independent director industry-specific CEO experience and green innovation.

	(1)	(2)	(3)	(4)
<i>INDCEODir</i>	−0.562*** (0.11)	−0.555*** (0.11)	−0.564*** (0.11)	−0.579*** (0.12)
<i>INDExp</i>				−0.048 (0.08)
<i>CEODir</i>				0.052 (0.07)
<i>CEOTenure</i>		−0.010*** (0.00)	−0.009*** (0.00)	−0.009*** (0.00)
<i>CEODual</i>		0.075*** (0.03)	0.079*** (0.03)	0.077*** (0.03)
<i>Salary</i>		−0.241*** (0.08)	−0.246*** (0.09)	−0.247*** (0.09)
<i>Bonus</i>		0.234** (0.10)	0.230** (0.10)	0.235** (0.11)
<i>OptionInc</i>		−0.136** (0.06)	−0.159** (0.06)	−0.156** (0.06)
<i>StockInc</i>		0.280*** (0.05)	0.282*** (0.05)	0.287*** (0.05)
<i>BSize</i>			0.007 (0.01)	0.006 (0.01)
<i>Indep</i>			0.439*** (0.17)	0.419** (0.17)
<i>FemDir</i>			−0.292** (0.14)	−0.288** (0.14)
<i>EduDiversity</i>			0.187** (0.08)	0.189** (0.08)
<i>NetworkSize</i>			0.058* (0.03)	0.058* (0.03)
<i>R&DExp</i>	−0.008 (0.02)	−0.007 (0.02)	−0.010 (0.02)	−0.009 (0.02)
<i>CapitalExp</i>	−0.411 (0.31)	−0.493 (0.31)	−0.432 (0.30)	−0.425 (0.30)
<i>Leverage</i>	−0.082 (0.08)	−0.049 (0.08)	−0.066 (0.08)	−0.068 (0.08)
<i>Size</i>	−0.014 (0.01)	−0.034*** (0.01)	−0.040*** (0.02)	−0.041*** (0.02)
<i>HHI</i>	−0.097 (0.28)	−0.170 (0.27)	−0.156 (0.27)	−0.167 (0.30)

(Continues)

TABLE 2 | (Continued)

	(1)	(2)	(3)	(4)
<i>AssetTang</i>	0.579*** (0.13)	0.613*** (0.13)	0.620*** (0.13)	0.615*** (0.13)
<i>Lag TotalApplications</i>	0.595*** (0.01)	0.596*** (0.01)	0.594*** (0.01)	0.593*** (0.01)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	7742	7742	7742	7742
<i>Pseudo R-squared</i>	0.363	0.365	0.365	0.365
<i>Wald Chi-Squared Test</i>	9679.572	9715.765	9842.118	9858.375

Note: This table reports the estimation results of the Poisson Maximum Likelihood Panel Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation (*GreenApplications*), controlling for year- and industry-fixed effects. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The probability of the Wald Chi-Squared Test examines the null hypothesis that all regression coefficients are equal to zero. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

Indep, was found to be statistically significant at the 1% level, contradicting studies on total innovation, which show an insignificant effect of board independence on innovation (Balsmeier et al. 2014; Kang et al. 2018). Interestingly, the presence of female directors, *FemDir*, exhibited a negative and significant sign on environmental innovation, opposing past research on CSR and eco-friendly firm outcomes (He and Jiang 2019; Nadeem et al. 2020; García-Sánchez et al. 2021; Moreno-Ureba et al. 2022). Nonetheless, this effect may be better viewed in the context of the riskiness of such activities, and in line with past research identifying the risk reduction tendencies of female directors on the board (Carter et al. 2017). Educational diversity, *EduDiversity*, appeared to increase environmental innovation, consistent with Hsieh et al. (2022) who looked at general firm innovation levels. Similarly, as was evinced in Chang and Wu (2021) who also examined general innovation, board connectedness, *NetworkSize*, was positively and significantly related to environmental innovation. In the last column of Table 2, Model 4, our primary concern was to ensure that our results were not solely driven by either industry-experienced directors or CEO-experienced directors. Therefore, in addition to including all firm-, CEO-, and board-level control variables, we incorporated the individual variables for industry experience and CEO experience among directors into the model. In this way, we safeguarded that the negative effect observed in Models 1, 2, and 3 of Table 2 reflects the combined influence of the two types of experience, over and above their individual effects. Even after the inclusion of these variables, the relation continued to maintain its negative and significant coefficient, establishing that board industry-specific CEO experience exhibits a tendency to reduce environmental innovation.

4.2 | Robustness

In this section, we present our investigation of the robustness of our results, which we obtained by conducting two alternative exercises: First, we estimated our baseline model in Equation (1), controlling for the presence of state unobserved heterogeneity by including state-fixed effects; second, we eliminated any

endogeneity concerns by employing the IV-GMM method with alternative instruments.

4.2.1 | Estimation With State-Fixed Effects

In our empirical models, we controlled for year- and industry-fixed effects. Nevertheless, as a second robustness test, we also considered the presence of unobserved regional factors (Audretsch and Feldman 1996)—for instance, local development or state environmental laws, which could promote or hinder environmental innovation. Thus, by imposing a state-fixed effect, we controlled for the possibility of any omitted variable biases arising from unobserved within-state changes that might have had an effect on green patent applications. Table 3, Models 1, 2, 3, and 4, repeat the empirical models in Table 2, which are based on Equation (1), controlling for year, industry, and state unobserved heterogeneity. Based on the results reported in Table 3, independent director industry-specific CEO experience is negative and statistically significant at the 1% level, confirming the findings of the baseline models.

4.2.2 | Endogeneity

Endogeneity has been mentioned in past literature as a threat to causal claims in research, but practices for tackling endogeneity in empirical work frequently diverge from the recommendations provided in the prior methodological reviews and commentaries (Hill et al. 2021). Reeb et al. (2012) attempted to explicate how endogeneity problems occur and why they are so prevalent in business research in a nontechnical fashion and pointed to the importance of identifying how the chosen research design best approximates a randomized-controlled experiment. The review conducted by Bliese et al. (2020) provided recommendations on how researchers can better apply fixed- and random-effects models, model time as a meaningful predictor, or make sure that unobserved time heterogeneity is controlled, and align hypotheses to analytic choice to facilitate theory development and enable communication between scholars from both macro- and micro-orientation.

TABLE 3 | Robustness: state-fixed effects.

	(1)	(2)	(3)	(4)
<i>INDCEODir</i>	−0.357*** (0.11)	−0.364*** (0.11)	−0.350*** (0.11)	−0.417*** (0.12)
<i>INDDir</i>				−0.051 (0.08)
<i>CEODir</i>				0.147** (0.07)
<i>CEOTenure</i>		−0.010*** (0.00)	−0.009*** (0.00)	−0.009*** (0.00)
<i>CEODual</i>		0.117*** (0.03)	0.110*** (0.03)	0.108*** (0.03)
<i>Salary</i>		−0.237*** (0.08)	−0.231*** (0.09)	−0.233*** (0.09)
<i>Bonus</i>		0.225** (0.11)	0.214** (0.11)	0.211* (0.11)
<i>OptionInc</i>		−0.051 (0.06)	−0.072 (0.06)	−0.066 (0.06)
<i>StockInc</i>		0.158*** (0.06)	0.170*** (0.06)	0.178*** (0.06)
<i>BSize</i>			0.017*** (0.01)	0.017** (0.01)
<i>Indep</i>			0.387** (0.17)	0.369** (0.17)
<i>FemDir</i>			−0.338** (0.14)	−0.318** (0.14)
<i>EduDiversity</i>			0.108 (0.08)	0.097 (0.08)
<i>NetworkSize</i>			0.027 (0.03)	0.026 (0.03)
<i>R&DExp</i>	−0.015 (0.02)	−0.014 (0.02)	−0.015 (0.02)	−0.016 (0.02)
<i>CapitalExp</i>	−0.119 (0.28)	−0.203 (0.28)	−0.153 (0.27)	−0.117 (0.27)
<i>Leverage</i>	−0.083 (0.09)	−0.057 (0.09)	−0.093 (0.09)	−0.101 (0.09)
<i>Size</i>	−0.019 (0.01)	−0.040*** (0.01)	−0.049*** (0.02)	−0.055*** (0.02)
<i>HHI</i>	0.049 (0.28)	0.013 (0.27)	−0.011 (0.27)	−0.004 (0.30)

(Continues)

TABLE 3 | (Continued)

	(1)	(2)	(3)	(4)
<i>AssetTang</i>	0.725*** (0.12)	0.767*** (0.12)	0.748*** (0.12)	0.735*** (0.12)
<i>Lag TotalApplications</i>	0.596*** (0.01)	0.598*** (0.01)	0.598*** (0.01)	0.596*** (0.01)
<i>Fixed Effects</i>	Year, industry, state	Year, industry, state	Year, industry, state	Year, industry, state
<i>Number of Observations</i>	7584	7584	7584	7584
<i>Pseudo R-squared</i>	0.375	0.377	0.377	0.378
<i>Wald Chi-Squared Test</i>	10408.990	10475.773	10588.939	10616.033

Note: This table reports the estimation results of the Poisson Maximum Likelihood Panel Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation (*GreenApplications*), controlling for year-, industry-, and state-fixed effects. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The probability of the Wald Chi-Squared Test examines the null hypothesis that all regression coefficients equal to zero.

The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

Thus, although the estimated baseline model, shown in Table 2, seemed to be robust to several control variables and unobserved heterogeneity, there were still concerns that these results may have been affected by several endogeneity issues related to omitted variables and reverse causality/simultaneity bias (Wooldridge 1997), which would have led to wrong inferences (Abdallah et al. 2015). More specifically, the results could have been driven by unobserved omitted variables, referring to the exclusion of variables simultaneously correlated with the regressors and with the response variable—for example, the ability of managers or elements of the organizational culture—or from reverse causality/simultaneity bias, whereby the green innovation was affecting the set of the regressors. Following the literature, we alleviated any endogeneity concerns and investigated the robustness of the results by conducting a series of endogeneity checks that included the instrumental variables (IV)-generalized method of moments (GMM) estimation using alternative instruments.

Our approach to addressing endogeneity included estimating Equations (1) under the GMM scheme, where the endogenous variables—namely, independent director industry-specific experience and environmental innovation—were instrumented, thus providing consistent estimates, especially in the presence of heteroscedasticity of unknown form (as opposed to the typical IV estimator, which, despite providing consistent coefficient estimates, does so with wrong standard errors) (Hansen 1982). In practice, under the GMM approach, the endogenous variables are regressed using a valid (orthogonal to the error term) and relevant (correlated with the endogenous variable) instrument. Following the literature (Durlauf and Ioannides 2010; Durlauf and Charles 2013; Flannery and Hankins 2013; Barro 2015; Liu et al. 2015; Obaydin et al. 2021), we estimated Equation (1) using four alternative sets of instruments. Considering Equation (1) where the endogenous variable is independent director industry-specific CEO experience, first, we used 5-year lag values of the endogenous variable as an instrument. According to Barro (2015), using lag values as instruments not only tackles endogeneity but also addresses any issues of measurement error. Second, we considered the mean value of the independent director industry-specific CEO experience for the other firms within

the same state. The rationale behind this instrumentation was that a firm's governance arrangements—in this case, the proportions of outside industry-CEO directors that it employs on its board—likely correlate with those enacted by its industry-CEO peers because firms follow similar industry norms; yet, such industry-CEO average is not likely to directly influence individual firm outcomes. Third, as an alternative instrument, we used the mean value of independent director industry-specific CEO experience for the other firms within the same city (Liu et al. 2015; Knyazeva et al. 2013) to gauge the local supply of directors. Following Knyazeva et al. (2013) and Liu et al. (2015), we deemed this instrument to be appropriate because the local supply of directors determines the presence of industry-specific CEO experts on the board. Further, the AddZip, which is the zip code where a firm is headquartered, can be considered as predetermined because such decisions occur at the early life stages of a firm and are unlikely to change.

Table 4 reports the IV-GMM estimation results for Equation (1). In Model 1, 5-year lag values of the endogenous variable is employed, in Model 2, the mean value of director industry-specific CEO experience of the other firms within the same State, in Model 3, the mean value of director industry-specific CEO experience of the other firms within the same City, in Model 4, the mean value of director industry-specific CEO experience of the other firms within the same AddZip, and in Model 5, the interaction term of noncompliant firms $\times$ post-SOX dummy. In all models, director industry-specific CEO experience was found to be positive and statistically significant at the 1%, confirming the findings of the baseline model. These results allow us to conclude that even after considering the potential of endogeneity, the support for the first hypothesis remains robust.

5 | Independent Director Industry-Specific CEO Experience and the Role of Industry Benchmarks

Given the reported negative effect of industry specific CEO experience on environmental innovation, we would like to investigate whether this effect corresponds to the industry norm, in other words, whether it is analogous to most similar peers

TABLE 4 | Robustness: endogeneity.

	(1)	(2)	(3)	(4)	(5)
<i>INDCEODir</i>	−1.438*** (0.28)	−3.536*** (1.06)	−1.237*** (0.24)	−1.389*** (0.20)	−11.949* (6.63)
<i>INDDir</i>	−0.077 (0.11)	0.022 (0.10)	−0.066 (0.09)	−0.059 (0.09)	−0.017 (0.15)
<i>CEODir</i>	0.194** (0.09)	0.439*** (0.12)	0.173** (0.07)	0.195*** (0.07)	1.150*** (0.26)
<i>CEOTenure</i>	−0.005* (0.00)	−0.007*** (0.00)	−0.006** (0.00)	−0.006** (0.00)	0.002 (0.00)
<i>CEODual</i>	0.134*** (0.04)	0.030 (0.04)	0.096*** (0.03)	0.091*** (0.03)	−0.159* (0.09)
<i>Salary</i>	−0.204** (0.10)	−0.266*** (0.10)	−0.136 (0.08)	−0.145* (0.08)	−0.503** (0.21)
<i>Bonus</i>	−0.213 (0.16)	−0.108 (0.13)	−0.136 (0.11)	−0.134 (0.11)	−0.003 (0.21)
<i>OptionInc</i>	−0.154** (0.07)	−0.084 (0.07)	−0.122* (0.06)	−0.119* (0.06)	0.099 (0.12)
<i>StockInc</i>	−0.013 (0.07)	0.060 (0.07)	0.022 (0.06)	0.025 (0.06)	0.189 (0.14)
<i>BSize</i>	0.014 (0.01)	0.021*** (0.01)	0.022*** (0.01)	0.022*** (0.01)	0.049** (0.02)
<i>Indep</i>	0.461** (0.23)	1.018*** (0.23)	0.784*** (0.18)	0.799*** (0.18)	1.701*** (0.66)
<i>FemDir</i>	−1.467*** (0.17)	−1.511*** (0.16)	−1.450*** (0.15)	−1.455*** (0.15)	−1.373*** (0.33)
<i>EduDiversity</i>	0.341*** (0.10)	0.194** (0.09)	0.142* (0.08)	0.145* (0.08)	0.789*** (0.30)
<i>NetworkSize</i>	−0.132*** (0.04)	−0.070** (0.04)	−0.040 (0.03)	−0.042 (0.03)	−0.233** (0.10)
<i>RnDExp</i>	−0.022 (0.04)	0.045* (0.02)	0.011 (0.02)	0.014 (0.02)	0.143* (0.09)
<i>CapitalExp</i>	−1.081*** (0.31)	−0.357 (0.32)	−0.710** (0.33)	−0.684** (0.32)	0.231 (0.89)
<i>Leverage</i>	−0.152 (0.10)	−0.196** (0.09)	−0.163* (0.09)	−0.166* (0.09)	−0.311** (0.16)
<i>Size</i>	−0.045** (0.02)	−0.063*** (0.02)	−0.035** (0.02)	−0.037** (0.02)	−0.124** (0.05)
<i>HHI</i>	−0.227* (0.12)	−0.258** (0.13)	−0.285** (0.11)	−0.283** (0.12)	0.049 (0.21)

(Continues)

TABLE 4 | (Continued)

	(1)	(2)	(3)	(4)	(5)
<i>AssetTang</i>	0.753*** (0.13)	0.664*** (0.12)	0.783*** (0.11)	0.772*** (0.11)	0.799*** (0.16)
<i>Lag_</i> <i>TotalApplications</i>	0.653*** (0.01)	0.616*** (0.01)	0.614*** (0.01)	0.614*** (0.01)	0.652*** (0.03)
	Lag values	State mean	City mean	AddZip mean	Noncompliant group × post- SOX dummy
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of</i> <i>Observations</i>	4948	7742	7742	7742	3886

Note: This table reports the IV-GMM Poisson Panel Regression results (Models 1–5) considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation (*GreenApplications*), using five alternative sets of instruments: In Model 1, 5-year lag values of the endogenous variable are employed; in Model 2, the mean value of the independent director's experience of the other firms within the same state; in Model 3, the mean value of the independent director's experience of the other firms within the same city; in Model 4, the mean value of the independent director's experience of the other firms within the same AddZip; and in Model 5, the interaction term of noncompliant firms × post-SOX dummy. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in the parentheses. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% level, respectively.

or whether it is a trend being evident in firms with industry-specific CEO experts on their boards. Since we found a diminishing effect in our results of Model 1, we specifically examined whether firms with such directors are more or less likely to underperform their peers in terms of green innovation (as captured by the variable *Under GreenApplications*).

To conduct this analysis, a Logit regression model is utilized to explore whether the tendency of directors with industry-CEO experts to reduce environmentally friendly innovations is justified with industry norms, particularly in comparison to its closest competitor. We identified each firm's most similar peer by leveraging the methodology established by Hoberg and Phillips (2010, 2016). This approach uses text-parsing algorithms to analyze the business descriptions in firms' 10-K filings. By converting the text into word usage vectors, the methodology creates a dynamic product market space in which firms are positioned based on how closely their descriptions align. This process results in new industry classifications that reflect firms' real-time competitive environments. Unlike traditional classification systems, which remain fixed over time, this method allows for yearly updates and provides a more flexible view of competition. Each firm is thus assigned a unique set of competitors based on its product descriptions, and the similarity scores between firms are calculated using these vectors.

In our analysis, we used the highest similarity score to determine each firm's closest peer, which helps us assess competitive dynamics and innovation efforts, particularly focusing on the number of green patent applications. The number of observations in this analysis is smaller than the full sample because not all firms have a most similar peer that are engaged in green innovation. If a firm's closest peer, as determined by the highest similarity score from the Hoberg and Phillips methodology, has no green patent applications, the comparison cannot be made, and consequently, the binary variable *GreenApplications* cannot be constructed in such cases. This reduces the total number of observations available for this analysis.

The results from Table 5 indicated that directors' industry-specific CEO experience does not have a statistically significant effect on the likelihood of a firm underperforming its most similar peer in environmental innovation, as measured by the variable *Under GreenApplications*. Across all four model specifications, the coefficient for *INDCEODir* consistently lacks statistical significance. This suggests that the presence of directors with industry-specific CEO experience does not influence the firm's relative performance in green innovation. The analysis is peer-relative, meaning that the firm's performance is benchmarked against its most similar competitor. This could imply that while such directors on average may reduce green innovation, they may also bring industry expertise to the board, and this influence translates into a rational reduction relative to industry peers and industry tendencies.

6 | When Does Independent Director Industry-Specific CEO Experience Matter?

6.1 | The Regulatory Environment

The discussion of boards' role in shaping firm strategy has been fuelled by a combination of contextual factors (Pugliese et al. 2009). For this reason, we employed the subsample analysis presented in Table 6 to investigate how directors' industry-specific CEO experience influences environmental innovation under regulatory environments, focusing specifically on firms' participation in the Regional Greenhouse Gas Initiative (RGGI). By dividing the sample based on firms operating in RGGI-participating states and over time (pre- and post-RGGI), the analysis aims to uncover whether and how the regulatory framework impacts the relationship between board composition and green innovation.

The first pair of models (Models 1 and 2) compares firms located in RGGI-participating states with those in non-RGGI states. To do so, we constructed the RGGI State variable,

TABLE 5 | Independent director industry-specific CEO experience and the role of industry benchmarks.

	(1)	(2)	(3)	(4)
<i>INDCEODir</i>	−0.196 (0.27)	−0.168 (0.27)	−0.081 (0.28)	−0.149 (0.30)
<i>INDDir</i>				0.001 (0.24)
<i>CEODir</i>				0.109 (0.20)
<i>CEOTenure</i>		−0.012* (0.01)	−0.010 (0.01)	−0.010 (0.01)
<i>CEODual</i>		0.210** (0.08)	0.193** (0.08)	0.190** (0.08)
<i>Salary</i>		−0.207 (0.21)	−0.209 (0.21)	−0.207 (0.21)
<i>Bonus</i>		−0.506 (0.36)	−0.500 (0.37)	−0.497 (0.37)
<i>OptionInc</i>		0.007 (0.22)	−0.058 (0.22)	−0.061 (0.22)
<i>StockInc</i>		0.190 (0.20)	0.204 (0.20)	0.207 (0.20)
<i>BSize</i>			−0.012 (0.02)	−0.011 (0.02)
<i>Indep</i>			0.927* (0.53)	0.918* (0.54)
<i>FemDir</i>			0.274 (0.41)	0.277 (0.41)
<i>EduDiversity</i>			−0.433** (0.21)	−0.446** (0.22)
<i>NetworkSize</i>			0.212*** (0.07)	0.214*** (0.07)
<i>R&DExp</i>	−0.149 (0.11)	−0.134 (0.11)	−0.150 (0.12)	−0.152 (0.12)
<i>CapitalExp</i>	−1.423 (0.92)	−1.552* (0.91)	−1.567* (0.92)	−1.528* (0.92)
<i>Leverage</i>	0.099 (0.22)	0.062 (0.22)	0.050 (0.22)	0.040 (0.23)
<i>Size</i>	0.009 (0.03)	−0.021 (0.03)	−0.043 (0.04)	−0.046 (0.04)
<i>HHI</i>	−0.900 (0.90)	−1.006 (0.92)	−1.138 (0.92)	−1.129 (0.92)

(Continues)

TABLE 5 | (Continued)

	(1)	(2)	(3)	(4)
<i>AssetTang</i>	−0.486 (0.38)	−0.471 (0.38)	−0.398 (0.39)	−0.425 (0.39)
<i>Lag TotalApplications</i>	−0.172*** (0.02)	−0.174*** (0.02)	−0.183*** (0.02)	−0.184*** (0.02)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	4355	4355	4355	4355
<i>Pseudo R-squared</i>	0.064	0.067	0.070	0.070
<i>Wald Chi-Squared Test</i>	291.739	300.201	316.654	317.229

Note: This table reports the estimation results of the Logit Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation relative to the most similar peer (*Under GreenApplications*), controlling for year- and industry-fixed effects. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The probability of the Wald Chi-Squared Test examines the null hypothesis that all regression coefficients equal to zero. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

which is a binary indicator that equals 1 if the firm operates in a state participating in the RGGI program when it was established (Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, Vermont, Maryland, Massachusetts, and Rhode Island), and 0 otherwise. These models focus solely on the geographic aspect of the regulatory framework. In contrast, Models 3 and 4 require that both the RGGI State variable and the After RGGI dummy (which is set to 1 from 2009 onward) be equal to 1 for firms to fall into the first category (Models 3) versus the rest (Models 4). This means that in Model 3, firms are in RGGI states, and the time period is after 2009. This setup allows for an investigation into how the combination of the regulatory environment (RGGI state participation) and the time period post-RGGI implementation impacts environmental innovation and enables us to examine whether firms in RGGI-participating states behave differently after the initiative was introduced.

The results reveal that in non-RGGI states (Models 2 and 4), *INDCEODir* has a consistently negative and significant effect on environmental innovation, regardless of the timing. Specifically, firms with industry-CEO experts on their boards are associated with reduced green innovation. This may suggest that in the absence of regulatory measures, where the firm needs to exercise discretion over the decision to pursue environmental innovation, such directors, being highly experienced within their respective industries, are becoming highly valuable in advising and monitoring such decisions.

On the other hand, in RGGI states (Models 1 and 3), the effect of *INDCEODir* is not statistically significant. This may not only indicate that the regulatory framework introduced by RGGI moderates the adverse impact of industry-experienced independent directors on environmental innovation, but it may also suggest that firms in RGGI-participating states may have been more proactive in adopting environmentally friendly practices even before the initiative officially began. This could indicate that these firms were more willing or prepared to comply with environmental regulations, possibly

anticipating the regulatory changes and aligning their strategies in advance.

6.2 | The Firm Environment

The effects of any green innovation initiated by firms with independent director industry-specific CEO experience may vary from firm to firm as a result of factors pertaining to firm-specific factors. We argued that firms with constrained financial resources, such as those with lower free cash flows or younger firms aiming to expand, may experience a stronger negative effect of director industry-specific CEO experience on green innovation, as these firms prioritize capital for growth over innovation.

6.2.1 | High Versus Low Free Cash Flows

We first argued that the negative impact of director industry-specific CEO experience on green innovation is more pronounced in firms with low free cash flows due to their limited financial flexibility and their need for superior advising to proceed with the worthiest projects, as well as for monitoring the CEO, ensuring that any use of FCF is towards optimal investments. Firms with lower free cash flows tend to have less discretionary capital available for investment in long term (Masulis and Reza 2023), uncertain projects like green innovation. Industry-CEO experts, who may be more conservative and focused on operational efficiency, may favor capital preservation over riskier investments. This risk aversion could inhibit innovation, as these directors may be more inclined to prioritize short-term financial stability over uncertain environmental projects.

To empirically test this hypothesis, we split the sample into two groups based on the mean level of free cash flows: (1) firms with low (below mean) free cash flows (Model 1) and (2) high (above mean) free cash flows (Model 2). As anticipated, the results of this analysis, presented in Table 7, confirmed the argument regarding the negative relationship between director

TABLE 6 | The regulatory environment.

	RGGI state		RGGI state and after RGGI	
	Yes (1)	No (2)	Yes (5)	No (6)
<i>INDCEODir</i>	−0.259 (0.33)	−0.554*** (0.13)	−0.731 (0.47)	−0.549*** (0.12)
<i>INDDir</i>	−0.272 (0.19)	−0.009 (0.08)	−0.247 (0.30)	−0.030 (0.08)
<i>CEODir</i>	0.059 (0.24)	0.019 (0.07)	0.686** (0.33)	0.027 (0.07)
<i>CEOTenure</i>	−0.007 (0.01)	−0.008*** (0.00)	−0.000 (0.01)	−0.009*** (0.00)
<i>CEODual</i>	−0.140** (0.07)	0.098*** (0.03)	−0.175* (0.11)	0.083*** (0.03)
<i>Salary</i>	−0.545*** (0.21)	−0.221** (0.09)	−0.608* (0.35)	−0.245*** (0.09)
<i>Bonus</i>	−0.152 (0.20)	0.297** (0.12)	−0.967* (0.52)	0.245** (0.11)
<i>OptionInc</i>	−0.065 (0.20)	−0.190*** (0.07)	−0.349 (0.24)	−0.176*** (0.07)
<i>StockInc</i>	−0.121 (0.21)	0.330*** (0.06)	−0.132 (0.32)	0.306*** (0.06)
<i>BSize</i>	−0.002 (0.02)	0.003 (0.01)	0.030 (0.03)	0.007 (0.01)
<i>Indep</i>	0.609 (0.43)	0.191 (0.18)	2.169*** (0.70)	0.330* (0.17)
<i>FemDir</i>	−0.604 (0.42)	−0.075 (0.15)	−0.161 (0.56)	−0.248* (0.15)
<i>EduDiversity</i>	0.104 (0.21)	0.245*** (0.08)	0.212 (0.29)	0.193** (0.08)
<i>NetworkSize</i>	−0.062 (0.09)	0.068** (0.03)	−0.160 (0.16)	0.061* (0.03)
<i>R&DExp</i>	−0.012 (0.03)	0.013 (0.04)	−0.002 (0.07)	−0.012 (0.03)
<i>CapitalExp</i>	−0.418 (0.45)	−0.405 (0.33)	−1.741 (1.09)	−0.345 (0.30)
<i>Leverage</i>	−0.482** (0.22)	0.076 (0.09)	−0.457 (0.32)	−0.030 (0.09)
<i>Size</i>	−0.014 (0.04)	−0.041** (0.02)	−0.036 (0.05)	−0.042** (0.02)

(Continues)

TABLE 6 | (Continued)

	RGGI state		RGGI state and after RGGI	
	Yes (1)	No (2)	Yes (5)	No (6)
<i>HHI</i>	−0.757 (1.22)	−0.223 (0.30)	−2.006 (1.57)	−0.026 (0.31)
<i>AssetTang</i>	1.823*** (0.35)	0.473*** (0.14)	2.052*** (0.53)	0.562*** (0.13)
<i>Lag TotalApplications</i>	0.648*** (0.04)	0.572*** (0.01)	0.610*** (0.05)	0.588*** (0.01)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	1485	6214	791	6910
<i>Pseudo R-squared</i>	0.414	0.360	0.420	0.361
<i>Wald Chi-Squared Test</i>	2560.579	8170.889	1506.572	8841.364

Note: This table reports the estimation results of the Poisson Maximum Likelihood Panel Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation (*GreenApplications*), controlling for year- and industry-fixed effects. The regression is conducted in subsamples based on whether the firm operates in a participating state in RGGI or not (Models 1 and 2) and based on whether the firm operates in a participating state in RGGI after the RGGI or not after (Models 3 and 4). A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The probability of the Wald Chi-Squared Test examines the null hypothesis that all regression coefficients equal to zero. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% level, respectively.

industry-specific CEO experience and green innovation, which appears significant in the low free cash flow subsample. This finding suggests that financial constraints play a critical role in shaping the decision-making processes of directors, particularly those with industry-specific CEO experience, in ways that inhibit environmental innovation.

6.2.2 | Young Versus Old Firms

We additionally looked at the context of younger and older firms. Specifically, we further argued that the negative impact of director industry-specific CEO experience on green innovation is particularly pronounced in younger firms, especially those seeking to expand. Younger firms typically have growth as a key priority and tend to allocate their available resources toward scaling operations, capturing market share, or investing in new technologies that offer immediate returns. In such firms, financial resources are often tight, and there is a greater need to allocate capital toward essential business functions rather than long term, uncertain initiatives like green innovation. Independent directors with industry experience may bring a strong focus on operational discipline and efficiency, prioritizing capital preservation and resource allocation strategies that maximize short-term profitability. In the case of younger firms, which are inherently more focused on growth, these directors may view green innovation as a secondary concern that could divert resources from expansion. Consequently, their influence can result in lower levels of green innovation, as they prioritize growth and financial stability over potentially risky environmental projects.

By splitting the sample based on mean firm age, i.e., younger (below mean age) firms (Model 3) versus older (above mean age) firms (Model 4), we examine how the relationship between

director industry-specific CEO experience and green innovation differs between younger, growth-oriented firms and older, more established firms. The results presented in Table 7 show that the negative relationship between such experience on the board and green innovation is significant in the younger firm subsample. This finding suggests that in younger firms, directors with CEO industry experience may emphasize capital efficiency and growth over innovation, which leads to lower levels of green innovation.

7 | The Quality of Environmental Innovation

Although granted patent performance is informative as far as the impact of industry-specific CEO experience on environmental innovation is concerned, we further investigated whether the negative relation evident in our findings is reflected in the impact and quality of these innovations. We, therefore, replaced our primary environmental innovation proxy in Equation (1) (total number of applications for each year for each firm, which subsequently resulted in granted patents) with green innovation citations. We used five different constructs to measure green innovation citations. First, to capture a firm's share of total green patent citations in a given fiscal year, allowing for comparison across time by controlling for annual variation in citation volumes, we utilized *GreenCitations1*, calculated as the total number of green patent citations received by a firm divided by the total green patent citations across all firms in the same fiscal year. Second, to capture the relative prominence of green innovation in the firm's overall patenting activity, we utilized *GreenCitations2*, calculated as a firm's green patent citations divided by its total patent citations. Third, we utilized *GreenCitations3* as a measure of average citation impact per patent, calculated as the total number of green patent citations received by a firm divided by the total number

TABLE 7 | The firm environment.

	Free cash flows		Firm age	
	Low (1)	High (2)	Low (3)	High (4)
<i>INDCEODir</i>	−1.057*** (0.19)	−0.228 (0.14)	−0.715*** (0.15)	−0.165 (0.18)
<i>INDExp</i>	−0.129 (0.13)	−0.016 (0.10)	−0.111 (0.10)	−0.080 (0.11)
<i>CEODir</i>	0.146 (0.12)	−0.025 (0.08)	0.023 (0.09)	0.100 (0.11)
<i>CEOTenure</i>	−0.019*** (0.00)	−0.005** (0.00)	−0.007** (0.00)	−0.014*** (0.00)
<i>CEODual</i>	0.060 (0.05)	0.050 (0.03)	0.026 (0.04)	0.173*** (0.04)
<i>Salary</i>	−0.065 (0.14)	−0.351*** (0.10)	−0.351*** (0.11)	0.029 (0.15)
<i>Bonus</i>	0.320* (0.19)	0.201 (0.13)	0.322** (0.15)	0.093 (0.16)
<i>OptionInc</i>	0.047 (0.12)	−0.248*** (0.08)	−0.212** (0.09)	−0.032 (0.08)
<i>StockInc</i>	0.336*** (0.10)	0.295*** (0.07)	0.349*** (0.08)	0.219** (0.09)
<i>BSize</i>	−0.003 (0.01)	0.012 (0.01)	−0.011 (0.01)	0.010 (0.01)
<i>Indep</i>	0.341 (0.31)	0.401** (0.20)	0.056 (0.23)	0.967*** (0.27)
<i>FemDir</i>	−0.267 (0.25)	−0.331* (0.18)	−0.092 (0.21)	−0.374* (0.19)
<i>EduDiversity</i>	−0.049 (0.14)	0.261*** (0.10)	0.016 (0.10)	0.269** (0.13)
<i>NetworkSize</i>	0.071 (0.05)	0.053 (0.04)	0.068* (0.04)	−0.026 (0.05)
<i>R&DExp</i>	0.007 (0.02)	−0.191 (0.17)	−0.076* (0.04)	0.486 (0.35)
<i>CapitalExp</i>	−0.508 (0.41)	−0.826** (0.40)	0.132 (0.33)	−1.177*** (0.34)
<i>Leverage</i>	0.120 (0.13)	−0.161 (0.12)	0.138 (0.12)	−0.392*** (0.12)
<i>Size</i>	−0.051** (0.03)	−0.021 (0.02)	−0.039* (0.02)	0.027 (0.02)

(Continues)

TABLE 7 | (Continued)

	Free cash flows		Firm age	
	Low (1)	High (2)	Low (3)	High (4)
<i>HHI</i>	0.585 (0.51)	−0.601* (0.31)	−0.832** (0.37)	0.342 (0.33)
<i>AssetTang</i>	1.265*** (0.20)	0.438** (0.18)	−0.304* (0.18)	1.809*** (0.15)
<i>Lag TotalApplications</i>	0.592*** (0.02)	0.588*** (0.02)	0.545*** (0.02)	0.652*** (0.02)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	3069	4618	4230	3331
<i>Pseudo R-squared</i>	0.384	0.360	0.280	0.450
<i>Wald Chi-Squared Test</i>	4247.028	8096.492	4200.678	6819.388

Note: This table reports the estimation results of the Poisson Maximum Likelihood Panel Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation (*GreenApplications*), controlling for year- and industry-fixed effects. The regression is conducted in subsamples based on whether the firm has low or high FCF (Models 1 and 2) and based on whether the firm has low or high Age (Models 3 and 4). A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The probability of the Wald Chi-Squared Test examines the null hypothesis that all regression coefficients equal to zero. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

of green patents granted to that firm. Fourth, to capture a firm's share of green patent citations within its industry, we utilized *GreenCitations4*, calculated as a firm's total green patent citations divided by the total green citations within its industry. Finally, *GreenCitations5* refines the fourth measure by accounting for both industry and year, offering a more granular view of a firm's citation performance relative to industry peers in the same year, calculated as a firm's green patent citations divided by the total green citations within the same industry and year. Collectively, these measures allow for a detailed evaluation of green innovation intensity and visibility at the firm level, over time, and within industry contexts.

Results, in Table 8, are unanimous across all constructs of environmental innovation citations, indicating no significant relationship between board industry-specific CEO experience and green patent citations. This suggests that, although industry-specific CEO experience reduces environmental innovation, the impact and quality of these innovations (as reflected by patent citations) remain unaffected.

8 | Independent Director Industry-Specific CEO Experience and Firm Performance and Value

To uncover the value of this reduction of environmental innovation caused by directors with industry-specific CEO experience and, therefore, its consequences on firm valuation and profitability, we estimated a panel model defined as

where the dependent variable initially corresponded to profitability (*ROA*) and, in subsequent models, to firm value (*Tobin's Q*). The set of the determinants included high independent director industry-CEO experience *HIGHINDCEODir*, and the dependent variable of green-granted patents, *GreenGranted*, along with the interaction term *HIGHINDCEODir*GreenGranted*. Similarly to Kang et al. (2018), the average time from applying for a patent to receiving it in our sample is 3 years. Therefore, we connected director industry-specific CEO experience variables from year $t-3$ to profitability in year t and firm value in years $t+1$, $t+2$, and $t+3$. We expected the valuation effects to be less immediate than profitability, thus the different treatment on timings.

The interaction term was aimed at capturing the profitability and valuation effects of green-granted patents initiated by firms with high industry-specific CEO experience on their boards. In addition to the same firm, CEO, and board-level controls used in Equation (1), we are controlling for past total innovation using the firm's total granted patents. The statistical adequacy of our model was also ensured by implementing the series of misspecification tests described in the previous section, thus addressing any issues of cross-sectional dependence/contemporaneous correlation, heteroscedasticity, serial correlation, stationarity, and functional form (uncovering the presence of a linear model). As with Equation (1), robust standard errors were clustered at the firm level.

Table 9 shows the panel estimation results for the dependent variable of *ROA* in Model 1 and *Tobin's Q* in Models 2, 3 and 4. In Model 1, green patents were found to be negatively and

$$Per_{i,t} = \alpha_i + \beta_1 HIGHINDCEODir_{i,t-3} + \beta_2 GreenGranted_{i,t} + \beta_3 GreenGranted_{i,t} * HIGHINDCEODir_{i,t-3} + \beta_4 CEOControls_{i,t-3} + \beta_5 BoardControls_{i,t-3} + \beta_6 FirmControls_{i,t-3} + \sum Industry_i^j + \sum year_t^j + e_{it} \quad (2)$$

TABLE 8 | The quality of environmental innovation.

	(1)	(2)	(3)	(4)	(5)
	GreenCitations1	GreenCitations2	GreenCitations3	GreenCitations4	GreenCitations5
<i>INDCEODir_(t-3)</i>	−0.006 (0.00)	−0.010 (0.01)	−0.045 (0.03)	−0.003 (0.00)	−0.008 (0.01)
<i>IndDir_(t-3)</i>	−0.001 (0.00)	−0.002 (0.01)	−0.016 (0.03)	−0.001 (0.00)	0.000 (0.01)
<i>CEODir_(t-3)</i>	0.005 (0.00)	0.001 (0.01)	0.025 (0.02)	0.002 (0.00)	0.005 (0.00)
<i>CEOTenure_(t-3)</i>	0.000 (0.00)	−0.000 (0.00)	0.000 (0.00)	−0.000 (0.00)	0.000 (0.00)
<i>CEODual_(t-3)</i>	−0.001 (0.00)	−0.002 (0.00)	−0.018* (0.01)	−0.001 (0.00)	−0.002 (0.00)
<i>Salary_(t-3)</i>	0.003 (0.00)	0.010* (0.01)	0.026 (0.02)	0.002* (0.00)	0.005 (0.00)
<i>Bonus_(t-3)</i>	0.003 (0.00)	0.003 (0.01)	0.060 (0.07)	0.003 (0.00)	0.005 (0.01)
<i>OptionInc_(t-3)</i>	0.000 (0.00)	0.005 (0.01)	0.011 (0.01)	0.002 (0.00)	−0.001 (0.00)
<i>StockInc_(t-3)</i>	0.000 (0.00)	−0.002 (0.00)	0.002 (0.02)	0.000 (0.00)	0.000 (0.00)
<i>BSize_(t-3)</i>	−0.000 (0.00)	−0.000 (0.00)	0.003 (0.00)	0.000 (0.00)	0.000 (0.00)
<i>Indep_(t-3)</i>	0.009 (0.01)	0.002 (0.01)	0.078 (0.08)	0.006* (0.00)	0.013 (0.02)
<i>FemDir_(t-3)</i>	−0.002 (0.01)	−0.004 (0.01)	−0.025 (0.03)	−0.004 (0.00)	−0.002 (0.01)
<i>EduDiversity_(t-3)</i>	0.000 (0.00)	−0.004 (0.00)	−0.018 (0.02)	−0.000 (0.00)	−0.001 (0.00)
<i>NetworkSize_(t-3)</i>	0.000 (0.00)	0.000 (0.00)	0.001 (0.01)	−0.000 (0.00)	−0.001 (0.00)
<i>R&DExp_(t-3)</i>	−0.001 (0.00)	−0.004 (0.00)	−0.006 (0.02)	0.000 (0.00)	−0.002 (0.00)
<i>CapitalExp_(t-3)</i>	−0.013 (0.02)	−0.004 (0.04)	0.002 (0.11)	−0.006 (0.01)	−0.007 (0.02)
<i>Leverage_(t-3)</i>	0.000 (0.00)	0.003 (0.01)	−0.002 (0.02)	0.001 (0.00)	0.000 (0.00)

(Continues)

TABLE 8 | (Continued)

	(1)	(2)	(3)	(4)	(5)
	GreenCitations1	GreenCitations2	GreenCitations3	GreenCitations4	GreenCitations5
<i>Size</i> _(t-3)	−0.001 (0.00)	−0.001 (0.00)	−0.005 (0.00)	−0.000 (0.00)	−0.001 (0.00)
<i>HHI</i> _(t-3)	−0.013** (0.01)	−0.007 (0.01)	−0.082* (0.05)	−0.004 (0.00)	−0.015 (0.01)
<i>AssetTang</i> _(t-3)	0.012 (0.01)	0.009 (0.01)	0.038 (0.07)	0.008* (0.01)	0.014 (0.01)
<i>Lag TotalCitations</i>	−0.000 (0.00)	0.001 (0.00)	−0.009 (0.01)	−0.000 (0.00)	−0.001 (0.00)
<i>Lag TotalGranted</i>	−0.001 (0.00)	−0.002 (0.00)	0.004 (0.01)	−0.000 (0.00)	−0.001 (0.00)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	6343	6343	6343	6343	6343
<i>R-squared</i>	0.007	0.011	0.038	0.031	0.019

Note: This table reports the estimation results of the Panel Regression considering the effect of independent directors' industry-specific CEO experience (*INDCEODir*) on Environmental innovation Impact, using five alternative proxies, controlling for year- and industry-fixed effects. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses.

The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

significantly related to *ROA*. As proposed by Elsayed and Paton (2005), investing in environmental innovation entails substantial short-term costs, and the benefits of such investments to the firm are reaped much later on (Arena et al. 2018). Additionally, in Models 2, 3, and 4, green innovation does not appear to have a significant effect on firm value. In untabulated tests, we found that the choice of green innovation level is critical, as high green innovation negatively impacts profitability, while medium levels of green innovation do not affect profitability and show a positive and significant relationship with firm value. We broke green innovation into three (low, medium, and high) or five levels. The indicators for 3- and 5-level were constructed by sorting firms based on the number of nonzero green patents granted. Results showed that medium levels of green innovation are not associated with reduced profitability (*ROA*) and significantly enhance firm value (Tobin's *Q*, $t + 3$).

High board industry-specific CEO experience emerged as being significantly related to *ROA*, but insignificantly related to Tobin's *Q*. Nonetheless, its interactive effect with green-granted patents was found to be positively and highly significant in all models in which *ROA* and Tobin's *Q* were the dependent variables. Director industry-specific CEO experience seemed to contribute to firm profitability and to help guide firms towards more rational, disciplined, and at the same time higher value-added green patent performance and quality. Hypothesis 2a was therefore confirmed. Green innovation performance appeared to be the channel through which

industry-specific CEO experience on the board supports firms in enhancing their profitability and value.

In regard to the control variables, similarly to Kang et al. (2018), firms were found to be more profitable when they are large with higher tangible assets, when they operate in less competitive markets, exhibiting lower levels of capital and R&D expenditures. Further, when the CEO's interests are well-aligned with those of shareholders, meaning that appropriate motives are in place to induce risk-taking (Sanders and Hambrick 2004), as reflected by bonus, stock, and option incentives, firms increase profitability. On the contrary, the effect of these variables on firm value varies, with *Salary* having a negative effect on firm value in the long run, with *Bonus* and *StockInc* affecting only firm value in the short run, and with option incentives not impacting long-term value. Consistent with past research, larger boards negatively affect firm profitability (Aktas et al. 2019), while they have an insignificant effect on firm value in the short run. Board independence appeared to verify past research findings, largely affecting firm value (Souther 2021). Moreover, the greater the percentage of female directors on the board causes an increase in firm profitability; yet, this effect does not survive for short- or long-term firm value, as also being demonstrated in Rose (2007). Greater educational diversity has been found not to relate to profitability and short-term firm value, corroborating past research in this area (Daily and Dalton 1994; Rose 2007). Board network size harms profitability in the short term but demonstrates a positive impact on firm value over the long term, as being previously found (Kim 2005).

TABLE 9 | Independent director industry-specific CEO experience and firm performance and value.

	(1) ROA	(2) Tobin's $Q_{(t+1)}$	(3) Tobin's $Q_{(t+2)}$	(4) Tobin's $Q_{(t+3)}$
<i>GreenGranted*HighINDCEODir</i>	0.004** (0.00)	0.519** (0.24)	0.621*** (0.24)	0.672*** (0.24)
<i>GreenGranted</i>	-0.004*** (0.00)	0.215 (0.20)	0.273 (0.20)	-0.028 (0.19)
<i>HighINDCEODir</i>	-0.006** (0.00)	-0.043 (0.31)	-0.209 (0.31)	-0.184 (0.31)
<i>IndDir_(t-3)</i>	-0.008 (0.01)	0.127 (0.68)	0.835 (0.73)	0.226 (0.75)
<i>CEODir_(t-3)</i>	-0.000 (0.01)	0.977 (0.63)	1.924*** (0.64)	2.161*** (0.68)
<i>CEOTenure_(t-3)</i>	-0.000 (0.00)	-0.024 (0.02)	-0.014 (0.02)	0.030 (0.02)
<i>CEODual_(t-3)</i>	-0.003 (0.00)	0.011 (0.25)	-0.016 (0.26)	-0.614** (0.26)
<i>Salary_(t-3)</i>	-0.036*** (0.01)	-0.905 (0.67)	-1.273* (0.69)	-1.184* (0.63)
<i>Bonus_(t-3)</i>	0.088*** (0.01)	3.086*** (1.01)	-0.283 (1.07)	-0.635 (1.11)
<i>OptionInc_(t-3)</i>	0.056*** (0.01)	1.290 (0.88)	0.892 (0.88)	0.820 (0.88)
<i>StockInc_(t-3)</i>	0.037*** (0.01)	1.293* (0.70)	1.075 (0.71)	0.285 (0.69)
<i>BSize_(t-3)</i>	-0.002** (0.00)	-0.005 (0.08)	0.038 (0.08)	0.133 (0.08)
<i>Indep_(t-3)</i>	-0.007 (0.02)	4.199*** (1.52)	2.777* (1.56)	3.589** (1.53)
<i>FemDir_(t-3)</i>	0.048*** (0.02)	-0.198 (1.65)	1.872 (1.61)	1.868 (1.53)
<i>EduDiversity_(t-3)</i>	-0.011 (0.01)	-0.658 (0.66)	-1.072 (0.67)	-1.202* (0.67)
<i>NetworkSize_(t-3)</i>	-0.009*** (0.00)	0.312 (0.20)	0.376* (0.20)	0.498** (0.20)
<i>R&DExp_(t-3)</i>	-0.019*** (0.01)	-0.384* (0.22)	-0.424 (0.31)	-0.336 (0.31)
<i>CapitalExp_(t-3)</i>	-0.121** (0.05)	5.384* (3.03)	3.122 (2.39)	1.733 (2.45)

(Continues)

TABLE 9 | (Continued)

	(1)	(2)	(3)	(4)
	ROA	Tobin's $Q_{(t+1)}$	Tobin's $Q_{(t+2)}$	Tobin's $Q_{(t+3)}$
<i>Leverage</i> _(t-3)	-0.005 (0.01)	4.814*** (1.22)	3.613*** (1.12)	2.071* (1.07)
<i>Size</i> _(t-3)	0.012*** (0.00)	0.064 (0.14)	0.002 (0.13)	-0.050 (0.13)
<i>HHI</i> _(t-3)	0.029** (0.01)	6.693** (2.73)	4.818* (2.84)	2.280 (2.62)
<i>AssetTang</i> _(t-3)	0.052*** (0.01)	-2.672** (1.26)	-2.985** (1.28)	-1.356 (1.32)
<i>Lag TotalGranted</i>	-0.000 (0.00)	-0.143 (0.12)	-0.252** (0.11)	-0.079 (0.11)
<i>Fixed Effects</i>	Year, industry	Year, industry	Year, industry	Year, industry
<i>Number of Observations</i>	6478	5894	5896	5890
<i>R-squared</i>	0.200	0.070	0.064	0.055

Note: This table reports the panel estimation results of the effect of the environmental innovation (considering granted patents) initiated by firms with high independent director's industry experience (*GreenGranted*HighINDCEODir*) on ROA and Tobin's Q, controlling for year- and industry-fixed effects. A detailed description of the variables can be found in Appendix A. Robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and * denote two-tailed statistical significance at the 1%, 5%, and 10% levels, respectively.

9 | Conclusion

This study provided new empirical evidence that board independent directors with CEO experience in a similar industry to the appointing firm tend to initiate value-enhancing environmental innovation strategies. Our findings showed that although the presence of similar industry CEOs on the board of directors reduces environmental innovation, this effect seems to be benchmarked to the industry norms and contributes to increased performance and firm value. Moreover, this effect is pronounced in regimes that lack environmental regulation; in other words, where environmental activity is rather discretionary and not obligatory. Finally, we ruled out various explanations of our findings, and our results remained robust in alternative specifications and tests.

We provided new insights into the relationship between independent directors' human capital and corporate outcomes, enriching our understanding of the importance of industry-specific CEO experience on the board. We demonstrate that such an experience seems to contribute to firm profitability and to help guide firms towards more rational, disciplined, and higher value-added environmental innovation. We offer guidance for various stakeholders. First, shareholders seeking a more proactive approach to addressing environmental innovation may consider forming boards that leverage industry-experienced CEO directors. Second, directors can use their CEO and industry expertise to more effectively oversee and challenge management, pushing the company beyond its current practices. Third, firms and top management teams lacking information on potential regulatory changes or industry environmental practices can rely on these directors for strategic advice and as a valuable source of information.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix A

Variable Description and Source

Variable	Description	Source
Independent variables		
HighINDCEODir	A binary variable set equal to 1 if the percentage of directors' industry-specific CEO experience (INDCEODir) is above the median percentage, and 0 otherwise.	BoardEx
INDCEODir	The number of independent directors who had current or past work experience as CEOs in the same sector (as reported in BoardEx), divided by the total number of a board's independent directors.	BoardEx
Control variables		
AssetTang	Asset intangibility, measured by intangible assets divided by total assets.	Compustat
BSize	Number of members on the firm's board.	BoardEx
CapitalExp	Annual capital expenditure divided by book assets.	Compustat
CEOBonus	Ratio of CEO bonus (cash and noncash) to total compensation.	Execucomp
CEODir	Number of independent directors who had current or past work experience as CEOs, divided by the total number of independent directors.	BoardEx
CEODual	Binary variable = 1 if the CEO was also chairman of the board, 0 otherwise.	BoardEx
CEOSalary	Ratio of CEO salary to total compensation.	Execucomp
CEOTenure	Number of years the CEO had held the position.	Execucomp
EducDiversity	Education heterogeneity measured with a Herfindahl index based on four education categories (no degree, diploma, bachelor, master+).	BoardEx
FemDir	Percentage of female directors = female directors/total directors.	BoardEx
GreenGranted	Total green-granted patents per firm per year. Log of (green granted +1). Data retrieved from USPTO datasets (Patent Assignment + Application Publication, Cooperative Patent Classification Y02).	USPTO
HHI	Sum of squared market shares of all firms in an industry. Higher values indicate less product market competition.	Compustat
IndDir	Independent directors with industry experience divided by total independent directors.	BoardEx
Indep	Percentage of independent directors on the board.	BoardEx
Leverage	Long-term debt plus current liabilities, divided by book assets.	Compustat
NetworkSize	Average overlaps in employment, activities, and education of all directors.	BoardEx
R&D	Annual R&D expenditure divided by book assets.	Compustat
Size	Natural logarithm of assets.	Compustat
TotalApplications	Patent applications per firm per year that resulted in granted patents. Log of (applications +1).	USPTO
TotalGranted	Granted patents per firm per year. Log of (granted +1).	USPTO
Dependent variables		
GreenApplications	Total green patent applications per firm per year that resulted in granted patents. Log of (applications +1).	USPTO
ROA	Return on assets: net income divided by book assets.	Compustat

Variable	Description	Source
Independent variables		
Tobin's Q	Market value of equity + book assets – stockholders' equity – deferred taxes, divided by book assets.	Compustat
UnderGreenApplications	Binary variable = 1 if firm's green applications < closest peer (per Hoberg and Phillips similarity classification), 0 otherwise.	Hoberg and Phillips Data Library
Moderating variables		
After RGGI	Binary variable = 1 from 2009 onwards, 0 otherwise.	Compustat
Firm age	Number of years since IPO.	Compustat
Free cash flows	Industry adjusted: income before extraordinary items + depreciation expense, scaled by total assets.	Compustat
RGGI state	Binary variable = 1 if firm operates in RGGI state (CT, DE, ME, NH, NJ, NY, VT, MD, MA, and RI), 0 otherwise.	Compustat
IV variables		
IV (AddZip)	Average independent director CEO industry experience of other firms within the same AddZip.	Compustat
IV (city)	Average independent director CEO industry experience of other firms within the same city.	Compustat
IV (state)	Average independent director CEO industry experience of other firms within the same state.	Compustat
Noncompliant group × post-SOX dummy	Interaction term: firms not meeting > 50% board independence pre-SOX combined with post-2002 indicator.	Compustat
Green innovation citations variables		
GreenCitations1	Firm's green patent citations/total green patent citations across all firms in same fiscal year.	USPTO
GreenCitations2	Firm's green patent citations/firm's total patent citations.	USPTO
GreenCitations3	Firm's green patent citations/total number of green patents granted to that firm.	USPTO
GreenCitations4	Firm's green patent citations/total green citations within its industry.	USPTO
GreenCitations5	Firm's green patent citations/total green citations within same industry and year.	USPTO