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Does National Innovation Layout Spur Eco-Innovation? The Upper Echelon's Role

Ali Meftah Gerged[1,2] | Ali Uyar[3] | Pornsit Jiraporn[4] | Abdullah S. Karaman[5]

[1]Management School, The University of Sheffield, Sheffield, UK | [2]Faculty of Economics and Political Science, Misurata University, Misrata, Libya | [3]CERIIM, Excelia Business School, La Rochelle, France | [4]Penn State Great Valley School of Graduate Professional Studies, Pennsylvania State University, Malvern, Pennsylvania, USA | [5]Winthrop University, Rock Hill, South Carolina, USA

Correspondence: Ali Meftah Gerged (a.m.gerged@sheffield.ac.uk)

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ABSTRACT

Numerous studies have examined whether financial and governance characteristics within firms promote eco-innovation. However, the influence of institutional contexts on eco-innovation, which is crucial for shaping effective policy and establishing key conditions, has not been adequately explored. Drawing on institutional, stakeholder, and upper-echelon theories, our study investigates the mechanisms through which a national innovation system (NIS) influences firms' commitment to eco-innovation. We specifically focus on the manufacturing sector worldwide, over the period from 2007 to 2018. Our findings reveal that the NIS is negatively associated with eco-innovation, contrary to expectations. This prompted us to delve deeper into three key components of the NIS. The analysis showed that although the quality of research institutions and government procurement of high-tech products negatively correlate with eco-innovation, university–industry collaboration positively affects it. Further exploration identified that environmental management teams and nonexecutive directors are critical moderators through which the NIS can enhance a firm's capacity for eco-innovation. Our evidence suggests several practical implications for theory, management practices, and policy formulation.

1 | Introduction

In the evolving landscape of global markets, the pressing need for sustainable development has positioned eco-innovation at the forefront of corporate and policy strategies (Dey et al. 2020; de Sousa and Melo 2021; Wang, Wei, and Wu 2023). Eco-innovation involves developing products and processes that significantly reduce environmental impacts or use natural resources more efficiently and responsibly (OECD 2009).[1] It is increasingly recognized as essential for achieving environmental objectives and boosting economic competitiveness (Gerstlberger, Praest Knudsen, and Stampe 2014; Bammens and Hünermund 2020; Sahasranamam and Soundararajan 2022). The success of eco-innovation efforts often depends on the broader innovation ecosystem within which firms operate (Yim and Kim 2005; Lundvall 2007).

The concept of the national innovation system (NIS), introduced by Freeman (1987) and expanded by Lundvall (1992) and Nelson (1993), provides a framework for understanding technology and information flows among people, enterprises, and institutions. The NIS framework underscores the importance of institutional arrangements and the systemic nature of innovation processes, emphasizing the critical interactions among research institutions, government bodies, and enterprises in shaping innovation outcomes (Edquist 2010). The NIS is pivotal in determining how businesses engage with eco-innovation influenced by national policies, corporate strategies, and cultural norms towards innovation. Lundvall's (1992) work highlights how public policy and institutional support are essential in creating an innovation-conducive environment (Lundvall 2007), and recent studies suggest that the NIS actively drive eco-innovative practices across industries directly linked to a country's economic and environmental policies (Fagerberg 2018; Madrid-Guijarro and Garcés-Torres 2023). Confirming these assertions, Uyar et al. (2024b) recently found that the NIS fosters firms' renewable energy use.

Critical elements of the NIS that influence eco-innovation include the quality of research institutions, the extent and effectiveness of university–industry collaboration, and government policies, particularly those related to high-tech product procurement (Cooke 2011). These elements either support or hinder eco-innovation in firms (Yang et al. 2021). High-quality research institutions are vital as they generate new scientific knowledge and develop advanced technologies that lead to eco-innovative solutions (Bozeman, Fay, and Slade 2013; Skute et al. 2019; Forliano, De Bernardi, and Yahiaoui 2021). University–industry collaborations bridge theoretical research and practical application, essential for translating academic research into commercial products that meet environmental standards (Bruneel, d'Este, and Salter 2010; Perkmann et al. 2013). Cohen, Nelson, and Walsh (2002) show that firms engaged with academic institutions are more innovative, including in eco-innovation. Additionally, government procurement policies focused on high-tech products significantly influence eco-innovation through demand-side pressures (Weber and Rohracher 2012; Kirchherr, Hartley, and Tukker 2023), with governments driving eco-innovation by adopting environmentally sound technologies and setting sustainability standards (Edler and Georghiou 2007; Rogge and Reichardt 2016).

This article, therefore, aims to explore how various NIS components affect firms' eco-innovation practices, offering a comprehensive review of the mechanisms through which institutional frameworks can support or constrain eco-innovation. This exploration seeks to illuminate the systemic nature of eco-innovation and its dependencies on the quality and interplay of different NIS actors. This analysis not only deepens the theoretical understanding of eco-innovation dynamics but also provides practical insights for policymakers to enhance the ecological impact of innovation practices.

However, the effectiveness of the NIS in promoting eco-innovation can be significantly influenced by internal corporate governance mechanisms (Chen and Song 2024; Han et al. 2023; Siswanti et al. 2024), particularly through the involvement of environmental management teams and the oversight of nonexecutive directors. Whereas the macro-environment set by the NIS is crucial, the micro-level governance within firms also plays a decisive role. These teams are tasked with integrating sustainable practices into the company's core strategic objectives (Gerged et al. 2023). They act as promoters for eco-innovation by ensuring that environmental considerations are embedded in the innovation process (Russo 2009). Their expertise and focus facilitate the alignment of eco-innovative initiatives with broader corporate goals, thus enhancing the company's responsiveness to environmental challenges (Dangelico and Pujari 2010).

Moreover, nonexecutive directors, who bring external perspectives and resources to the board, are increasingly seen as vital in reinforcing eco-innovation. Their oversight ensures that environmental policies not only comply with legal standards but also align with best practices and stakeholder expectations (Cormier, Magnan, and Van Velthoven 2005; Spitzeck 2009). By moderating the relationship between the NIS and corporate eco-innovation, nonexecutive directors can influence the strategic direction of the company, ensuring that sustainable practices are not only adopted but are effectively implemented (Daily, Dalton, and Cannella 2003; De Villiers, Naiker, and Van Staden 2011).

The interplay between the NIS and the internal factors concludes in a complex yet intriguing dynamic that shapes companies' eco-innovation landscapes. Thus, this article also seeks to explore this dynamic further by examining how environmental management teams and nonexecutive directors moderate the impact of the NIS on corporate eco-innovation. Through this exploration, we aim to provide a comprehensive understanding of the mechanisms through which governance structures can either hinder or enhance the capacity for eco-innovation within firms operating within various national innovation contexts.

This study focuses on an international sample of manufacturing industries, containing 14,973 firm-year observations spanning from 2007 to 2018. By integrating institutional, stakeholder, and upper-echelon theories, we investigated the relationship between a composite proxy of NISs and eco-innovation. Contrary to expectations, we discovered a negative association between the NISs and eco-innovation. Prompted by these unexpected findings, we further dissected the composite NIS proxy into three key components. The analysis revealed that although the quality of research institutions and government procurement of high-tech products continue to exhibit a negative relationship with eco-innovation, university–industry collaboration demonstrates a positive association. This suggests that collaborative efforts between academia and industry are crucial in fostering eco-innovative outcomes. Further exploration identified environmental management teams and nonexecutive directors as critical moderators through which the NIS can enhance a firm's capacity for eco-innovation. These findings highlight the complex interplay between various elements of the NIS and internal governance and their joint impacts on eco-innovation within the manufacturing sector. We have chosen the manufacturing sector due to its repercussions on environmental externalities associated with production, supply chain, and shipping activities.

This study offers three main contributions to the discourse on the NIS and eco-innovation. First, it conducts a detailed analysis of how the quality of research institutions, the synergy between universities and industry, and government procurement strategies influence eco-innovation within firms. The research highlights the dual role of these institutional elements, both as enablers and as barriers, thus informing strategic policy decisions and business practices aimed at enhancing the environmental impact of innovation. Second, the study critically examines the role of internal corporate governance mechanisms, particularly environmental management teams and nonexecutive directors, in moderating the relationship between the NIS and corporate eco-innovation. It reveals how these governance structures can either support or inhibit eco-innovation through their alignment with the broader innovation ecosystem established by the NIS. This detailed exploration aids in understanding the complexities of incorporating sustainable practices within corporate governance, offering insights into more effective governance models that foster eco-innovation. Third, utilizing an extensive dataset of 14,973 firm-year observations from 2007 to 2018, the research provides robust international empirical evidence on the dynamics between the NIS and corporate eco-innovation practices. The findings challenge conventional understanding by revealing a negative correlation between certain NIS components and eco-innovation, alongside a positive impact from university–industry collaborations. These surprising results necessitate a re-evaluation of existing policies and prompt a reassessment of strategies to enhance sustainable innovation. Collectively, the study significantly enhances both the theoretical and practical understanding of eco-innovation. It scrutinizes the roles of various actors within the NIS, illustrating how their interactions with internal governance can either facilitate or hinder sustainable business practices. This comprehensive analysis is crucial for developing strategies that effectively integrate eco-innovation into national and corporate frameworks, advancing the agenda of sustainable development.

Following the introduction, the article moves to Section 2, where it explores the theoretical framework and formulates hypotheses. Section 3 then outlines the research methodology used. Section 4 discloses the results of the empirical analysis. The article concludes with Section 5, followed by Section 6 providing discussions for both the theoretical implications and practical applications of the study, acknowledges its limitations, and suggests avenues for further research.

2 | Theories and Hypotheses

2.1 | NIS and Corporate Eco-Innovation

Institutional theory suggests that organizational behaviors, including those related to innovation, are deeply shaped by the structures and norms that organizations operate within. These influences emerge through different types of institutional pressures—namely, mimetic, normative, and coercive pressures (Scott 1995). The theory can be applied to hypothesize that the NIS enhances eco-innovation by examining how these pressures translate into eco-innovative outcomes.

Normative pressures originate from the standards and expectations that define organizational goals and the means to achieve them (DiMaggio and Powell 1983). Within the NIS, the quality of research institutions and the nature of university–industry collaborations represent such pressures. Firstly, high-quality research institutions are crucial in driving eco-innovation by setting high academic and ethical standards, generating innovative knowledge, and providing personnel dedicated to sustainability (Bozeman, Fay, and Slade 2013; Dusdal and Powell 2021). These institutions inherently promote values that prioritize environmental sustainability, fostering the development of new eco-friendly technologies (Forliano, De Bernardi, and Yahiaoui 2021). Secondly, the permeation of these norms throughout the business sector encourages firms to adopt these eco-innovative standards. Collaborative interactions between universities and industries act as tools for the transfer of knowledge and innovative capabilities (Perkmann et al. 2013), embedding firms within networks that support and expect environmentally conscious innovations (Ankrah and Omar 2015; Klofsten et al. 2019; Rybnicek and Königsgruber 2019).

On the other hand, coercive pressures, which are formal or informal pressures from organizations that entities depend on or from societal cultural expectations (DiMaggio and Powell 1983), also play a role. Government procurement policies are a form of coercive pressure when they mandate or strongly favor eco-innovative solutions. Such policies compel firms to align their innovation strategies with high-tech, environmentally friendly products (Edler and Georghiou 2007; Flanagan, Uyarra, and Laranja 2011; Weber and Rohracher 2012), thereby coercing them to adopt eco-innovation as standard practice to maintain competitiveness and eligibility for government contracts (Rogge and Reichardt 2016; Demircioglu and Audretsch 2017; Fagerberg 2018).

This theoretical framework allows us to understand how different components of the NIS impact corporate eco-innovation through varied institutional pressures. By establishing hypotheses based on these pressures, this study delineates the pathways through which quality research institutions, university–industry collaborations, and government procurement policies shape eco-innovative activities within firms. Empirical testing of these hypotheses would enrich the eco-innovation literature and provide strategic insights for leveraging institutional arrangements to bolster the ecological impact of corporate innovation practices. Therefore, we propose the following hypotheses:

Hypothesis 1. *The NIS is positively associated with corporate eco-innovation.*

Hypothesis 1a. *The quality of research institutions, as a proxy for normative pressure, positively influences corporate eco-innovation.*

Hypothesis 1b. *University–industry collaboration, as a proxy for normative pressure, positively influences corporate eco-innovation.*

Hypothesis 1c. *Government procurement of high-tech products, as a proxy for coercive pressure, positively influences corporate eco-innovation.*

2.2 | The Moderating Impact of the Environmental Management Team

The relationship between the NIS and corporate eco-innovation is complex and influenced by a variety of factors at both internal and external levels. Stakeholder theory suggests that organizations are shaped by the interests of different groups, including government agencies, consumers, and internal management teams (Freeman 1984). Simultaneously, upper-echelon theory indicates that the backgrounds, experiences, and strategic choices of senior management critically affect organizational outcomes (Hambrick and Mason 1984). Applying these theories to environmental management helps explain how environmental management teams influence a firm's eco-innovation within the NIS framework.

Stakeholder theory also asserts that a company's strategic direction is formed by the demands and priorities of both external and internal stakeholders (Freeman 1984). In the context of the NIS, external stakeholders like government agencies and regulatory bodies establish the policies and incentives that promote eco-innovation (Berrone et al. 2013; Watson et al. 2018; Arici and Uysal 2022; Hu, Wang, and Wang 2021). Environmental management teams are crucial internally for aligning these external policies with the firm's capabilities and strategic goals (Scarpellini et al. 2020). With their specialized knowledge and dedication to sustainability, environmental management teams often lead the way in integrating these external policies into the company's strategic plans (Sharma and Vredenburg 1998; Valero-Gil et al. 2023).

Upper-echelon theory contends that the strategic decisions and outcomes of an organization reflect the values and cognitive orientations of its top management (Hambrick and Mason 1984). The skills and commitment to sustainability of environmental management teams can greatly determine how effectively a company takes advantage of the opportunities for eco-innovation offered by NIS (Waldman and Siegel 2008; Metcalf and Benn 2013; Stahl et al. 2020). The proactive and informed involvement of environmental management teams ensures that strategic goals driven by NIS policies are not just met but also leveraged as catalysts for innovation and competitive advantage (Carpenter, Geletkanycz, and Sanders 2004; Damanpour and Schneider 2009; Miao et al. 2018).

Drawing on stakeholder and upper-echelon theories, it is clear that environmental management teams play a vital moderating role in the relationship between the NIS and corporate eco-innovation. Their ability to navigate between external pressures and internal strategies and resources is essential. Thus, the following hypothesis is proposed:

Hypothesis 2. *Environmental management teams significantly moderate the relationship between NIS and corporate eco-innovation, such that the presence of a proactive and capable environmental management team strengthens the positive impacts of NIS on eco-innovation.*

2.3 | The Moderating Role of Nonexecutive Directors

To explore the moderating role of nonexecutive directors in the relationship between the NIS and corporate eco-innovation, we rely on stakeholder theory and upper-echelon theory. Stakeholder theory asserts that organizations are shaped by the demands and interests of various stakeholder groups, necessitating strategies that align with broad social and environmental standards (Freeman 1984). In the context of eco-innovation, stakeholders such as governments, consumers, and environmental groups pressure companies to implement sustainable practices (Hart and Sharma 2004; Javed et al. 2023). The upper-echelon theory offers a perspective on how top executives and directors, influenced by their experiences, values, and personalities, affect organizational outcomes, particularly in areas like sustainability and innovation that require specialized knowledge (Hambrick and Mason 1984; Zahra and Pearce 1989; Zaman et al. 2024).

Nonexecutive directors play a crucial role as gatekeepers of compliance and strategic alignment with environmental standards, integrating stakeholder demands into company strategies. Their influence is essential in how companies respond to the innovation demands set by NIS, which cover regulatory, technological, and market dimensions (Freeman 1987; Lundvall 1992). With their strategic oversight and ability to direct resources towards innovation, nonexecutive directors are key drivers of eco-innovation.

Previous research showed that a director's commitment to sustainability can boost a company's eco-innovation by embedding environmental considerations into the innovation process and aligning company strategies with national innovation agendas (Ullah and Nasim 2021). The varied expertise and external connections of nonexecutive directors also improve a company's capacity to absorb external knowledge from the NIS into eco-innovation practices (Cohen and Levinthal 1990). Prior empirical studies also highlighted the influence of board characteristics, like those of nonexecutive directors, on sustainability initiatives. For instance, Galbreath (2011) discovered that boards with diverse expertise and robust governance frameworks are more likely to enact effective environmental strategies. Similarly, Walls, Berrone, and Phan (2012) noted the impact of board composition on fostering green practices under institutional pressures. These findings suggest that nonexecutive directors, by bridging external drivers of innovation and internal strategic capacities, not only foster the adoption of eco-innovation but also ensure it aligns with both national objectives and stakeholder expectations. Given these considerations, the hypothesis can be framed as follows:

Hypothesis 3. *Nonexecutive directors significantly moderate the relationship between the NIS and corporate eco-innovation, such that their involvement enhances the firm's capability to translate the NIS inputs into eco-innovative outcomes.*

Figure 1 shows the theoretical model indicating developed hypotheses.

3 | Sample Selection and Data Description

3.1 | Sample Selection

The sample of the study includes the manufacturing sector (NAICS 31-33). We have selected the manufacturing sector for two reasons; one is to obtain a homogeneous sample, and the other one is the manufacturing sector's repercussions on environmental concerns. Our sample period covers 2007–2018 due to the availability of the NIS data for this period in the data source (the Global Competitiveness Index published by the World Economic Forum).[2] We obtained the data for the study from three sources, namely, the Global Competitiveness Index, the London Stock Exchange Group (LSEG) Workspace database (formerly known as Thomson Reuters Eikon/Refinitiv database), and the World Bank.[3] After matching the data obtained

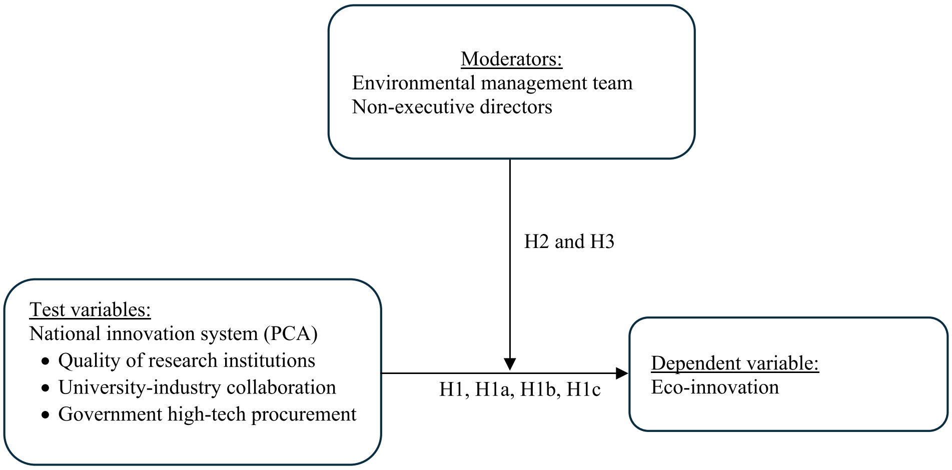

FIGURE 1 | The theoretical model shows developed hypotheses.

from those three sources and deletions due to missing data, we had 14,973 out of 15,538 initial observations.[4]

3.2 | Variables Description

Dependent variable: The eco-innovation variable was proxied by the eco-innovation dimension score of the environmental pillar of ESG[5] taxonomy in the LSEG Workspace database. Eco-innovation measures a firm's engagement with lessening environmental externalities, costs, and drawbacks, hence creating new environmental technologies, processes, and eco-friendly products and services (score ranges from 0 to 100) (Fiorillo et al. 2022; Uyar et al. 2023). Eco-innovation score is drawn on 20 metrics, namely, eco-labeled product development, fuel consumption, noise-reducing product development, hybrid vehicle development, environmental screening criteria in investments, total fleet's average CO_2 emissions, the percentage of labeled wood or forest products (e.g., Forest Stewardship Council) from total wood or forest products, organic food development, production and distribution of agrochemicals, nuclear energy production percentage, product or technology development for use in the clean, product or technology development for water use efficiency, renewable energy, product or service development for energy efficiency of buildings, total amount of environmental research and development (R&D) costs, the company's commitment to the Equator Principles, leasing or marketing buildings that are certified by recognized real estate certifications, revenue from environmental products and services, recycling program commitment, and public commitment to divest from fossil fuel (some indicators are sector specific like hybrid vehicle development). The data for the eco-innovation were collected from the LSEG Workspace database.

Independent variables: Following Ndou, Schiuma, and Passiante (2018), Cirillo et al. (2019), and Uyar et al. (2024b), the NIS is measured with a composite indicator based on three proxies, namely, the quality of scientific research institutions, the extent of university–industry collaboration on R&D, and government support for fostering innovation via high-etch procurement. We assess the quality of the NIS using a national innovation score derived through principal component analysis (PCA). This score combines three key factors: (1) the quality of research institutions, (2) government procurement of high-tech products, and (3) university–industry collaborations. By employing PCA, we create a composite NIS score that encapsulates these dimensions. Alternatively, we also calculate the NIS score by adding up the individual scores of the three components. The results based on both methods are similar; hence, for conciseness, we present only those derived from the PCA-based national innovation score. These three proxies of the NIS are scored on a scale of 1–7, with 1 showing a weak NIS and 7 showing a high level of NIS. The data for these country-level proxies were fetched from the Global Competitiveness Report disseminated by the World Economic Forum (WEF 2018). The Global Competitiveness Report provides data on the competitiveness of the countries worldwide yearly (Ali, Kelley, and Levie 2020). It is a reliable source of data for evaluating the public governance efficiency and institutional environment of nations (Uyar et al. 2024b).

Moderating variables: We use two proxies for moderating effects, namely, the environment management team and nonexecutive board members. The environmental management team is measured with a binary variable showing the existence (i.e., one) or not (i.e., zero) (Soana 2024), whereas nonexecutive board members are the proportion of directors on the board (Uyar et al. 2024a) who hold no executive position in firms.

Control variables: Finally, we control a battery of factors that are likely to influence the eco-innovation of firms. Due to the fact that the boards are the main governance body in formulating corporate financial and nonfinancial policies, we control board size, board gender diversity, nonexecutive directors, and CEO duality (Govindan et al. 2021; Uyar et al. 2023; Uyar et al. 2024a). For example, larger boards might be less efficient in decision-making, female and nonexecutive directors are more likely to protect stakeholders' interests, and powerful CEOs are keen on exerting their power and stewardship in board decisions. Among the financial attributes, we control firm size, return on assets, leverage, R&D, and cash holding (Govindan et al. 2021; Uyar et al. 2023; Valero-Gil et al. 2023; Uyar et al. 2024a; Zaman et al. 2024). Larger firms are more exposed to public scrutiny, high-profit and high-cash-holding firms might have more financial resources to commit to eco-innovation, indebtedness might limit firms' ability to finance eco-innovation, and innovative firms might shift their innovation capacity for eco-innovation. We control free float shares as firms' ownership base is important due to the ultimate control of stockholders on firm practices (Govindan et al. 2021; Uyar et al. 2023; Uyar et al. 2024a). Finally, we control the Worldwide Governance Indicators as the external environment and regulatory power design the environment in which firms operate and shape their policies accordingly (Uyar et al. 2024a; Zaman et al. 2024). Whereas board, financial, and ownership data were sourced from the LSEG Workspace database, the Worldwide Governance Indicators were obtained from the World Bank.[6] The variable definitions are shown in Table A1. All continuous variables are winsorized at the 1% and 99% levels.

3.3 | Empirical Methodology

To estimate the impact of the NIS on eco-innovation, we employ the following regression model:

$$\mathrm{Eco-innovation}_{\mathrm{ijt}} = \beta_0 + \beta_1 \mathrm{NIS}_{\mathrm{jt}} + \beta_2 \mathrm{Controls}_{\mathrm{ijt}} + \varepsilon_{ijt}$$

where i indexes firms, j indexes countries, and t indexes years. The definitions of the variables can be found in Table A1. To mitigate omitted variable bias, we include firm, country, and year fixed effects. In addition to our primary regression analysis, we conduct several robustness checks, such as propensity score matching, entropy balancing, and regression analysis using changes in the variables. These methods help ensure the robustness and reliability of our results (Rosenbaum and Rubin 1983; Hainmueller 2012). Furthermore, we decompose NIS into three components—each analyzed separately to gain deeper insights into their individual impacts on eco-innovation.

To explore potential interaction effects, we run additional regression analyses incorporating interaction terms. First, we examine the moderating effect of the environmental management team between the NIS and eco-innovation with the following model:

$$\begin{aligned}\mathrm{Eco-innovation}_{\mathrm{ijt}} = {} & \beta_0 + \beta_1 \mathrm{NIS}_{\mathrm{jt}} \times EMT_{jt} + \beta_2 \mathrm{NIS}_{\mathrm{jt}} \\ & + \beta_3 \mathrm{EMT}_{\mathrm{jt}} + \beta_4 \mathrm{Controls}_{\mathrm{ijt}} + \varepsilon_{ijt}\end{aligned}$$

where EMT represents the existence of the environmental management team or not. This model allows us to investigate how the effectiveness of the NIS might be moderated by the existence of the firm's environmental management team.

Similarly, we examine the role of nonexecutive board members with the following model:

$$\begin{aligned}\mathrm{Eco-innovation}_{\mathrm{ijt}} = {} & \beta_0 + \beta_1 \mathrm{NIS}_{\mathrm{jt}} \times NEBM_{jt} + \beta_2 \mathrm{NIS}_{\mathrm{jt}} \\ & + \beta_3 \mathrm{NEBM}_{\mathrm{jt}} + \beta_4 \mathrm{Controls}_{\mathrm{ijt}} + \varepsilon_{ijt}\end{aligned}$$

where NEBM stands for nonexecutive board members' proportion on the board. This analysis helps us understand whether the proportion of nonexecutive board members influences the relationship between the NIS and eco-innovation.

By employing these rigorous methodologies and robustness checks, we aim to provide a comprehensive analysis of the factors driving eco-innovation within firms across different countries and years.

4 | Results

4.1 | Descriptive Statistics

Table 1 shows the summary statistics. Given that the eco-innovation score ranges from 1 to 100, the mean score of eco-innovation (31.91) shows that the firms in the sample need to improve their eco-innovation capacity. However, we note that the mean value of eco-innovation in our sample dedicated to the manufacturing sector is relatively above the mean value of eco-innovation in other studies in the energy sector with 12.49

TABLE 1 | Summary statistics.

Variable	Mean	SD	25th	Median	75th
Eco-innovation	31.91	32.29	0.00	26.34	57.65
Quality of research institutions	5.44	0.74	5.06	5.69	5.99
University–industry collaboration	5.02	0.74	4.61	5.09	5.67
Government high-tech procurement	4.15	0.53	3.85	4.16	4.44
National innovation system (PCA)	0.03	1.52	−0.76	0.28	1.21
Board size	10.28	3.44	8.00	10.00	12.00
Board gender diversity	12.53	12.06	0.00	11.11	20.00
Nonexecutive directors	71.10	24.51	60.00	78.57	88.89
CEO duality	0.43	0.49	0.00	0.00	1.00
Firm size	22.14	1.59	21.22	22.15	23.12
Return on assets	0.08	0.10	0.04	0.08	0.12
Leverage	0.22	0.15	0.10	0.22	0.33
Free float	77.16	24.57	59.71	88.00	98.21
Research and development	0.03	0.05	0.00	0.00	0.03
Cash holdings	0.10	0.11	0.02	0.06	0.13
Worldwide governance indicator	1.07	0.61	1.09	1.24	1.37

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1.

(Uyar et al. 2023) and cross-sector study with 21.22 (Karaman et al. 2024) and 23.54 (Zaman et al. 2024). Nevertheless, it seems that eco-innovation practices have a higher adoption rate in developed countries with 45.72 (Albitar et al. 2024). On the other hand, all three proxies of the NIS are slightly higher than the moderate level considering the range of the scores (i.e., 1–7 [best]). Whereas the quality of research institutions has a mean of 5.44, the university–industry collaboration has a mean of 5.02, and the government high-tech procurement has a mean of 4.15. These values align with Uyar et al.'s (2024b) study conducted in a cross-sector context. Although firms' average board size is 10.28 directors, they have a high nonexecutive director ratio (71.10%) but a low percentage of female directors (12.53%). The board characteristics' mean values largely align with prior studies' mean values (Uyar et al. 2023; Albitar et al. 2024; Karaman et al. 2024). However, we underscore that the female directors' ratio on board in our study is lower than that of service firms (Galletta et al. 2022). Other summary statistics can be found in Table 1.

4.2 | Correlation Analysis

The pairwise correlation between variables is analyzed through Pearson correlation analysis. In Table 2, it shows that eco-innovation is positively correlated with NIS. Besides, it appears that larger and more gender-diverse boards are positively associated with more co-innovation, but NEBM is negatively associated with it. Furthermore, whereas larger and more leveraged firms are more likely to do eco-innovation, more R&D-intensive and cash-holding firms are less likely to do eco-innovation. Other coefficients are observable in Table 2. Overall, the correlation coefficients lower than 0.7 indicate the nonexistence of multicollinearity issues as well (Hammer et al. 2022).

4.3 | Baseline Regression Results

Table 3 displays the regression results, where eco-innovation is the dependent variable. Model 1 includes the NIS as the only independent variable, whereas Model 2 includes the NIS and all the control variables. In both models, the coefficients of the NIS are negative and significant.[7] This is unexpected and intriguing as NIS is anticipated to have a positive impact on eco-innovation. Hypothesis 1 does not appear to be supported. In terms of economic magnitude, using a standardized coefficient, we estimate that a rise in the NIS score results in a decline in eco-innovation by 2.59%.[8] Obtaining an unexpected result (i.e., negative association) motivated us to deepen the investigation with the components of NIS. We report and comment on the outcomes of this additional test in the following section.

4.4 | Analysis of Specific Factors

To gain deeper insights, we analyze the components of the NIS, recognizing that various components may have different effects on eco-innovation. Table 4 breaks down the NIS into three distinct components. The coefficients for the quality of research institutions and government procurement of high-tech products are significantly negative, whereas the coefficient for university–industry collaboration is significantly positive. These findings are noteworthy, indicating that not all aspects of the NIS affect eco-innovation similarly. University–industry collaborations emerge as a key factor in enhancing eco-innovation. Consequently, Hypotheses 1a and 1c are not supported, as the quality of research institutions and government procurement of high-tech products do not enhance eco-innovation. However, Hypothesis 1b is corroborated, for university–industry collaborations have a positive impact on eco-innovation.

4.5 | Interaction Effects

In this section, we investigate Hypothesis 2 by examining the interaction effect between the NIS and environment management team using an interaction term. Table 5 shows the regression result. The coefficient of the interaction term between the NIS and the environment management team is significantly positive, corroborating Hypothesis 2. The environment management team serves as a crucial moderator in the relationship between the NIS and corporate eco-innovation. Their expertise in balancing external pressures with internal strategies and resources is indispensable.

Furthermore, we examine Hypothesis 3 by incorporating an interaction term between the NIS and nonexecutive directors. The results, displayed in Table 6, reveal that the coefficient of the interaction term is significantly positive, supporting Hypothesis 3. This indicates that nonexecutive directors significantly enhance the impact of the NIS on eco-innovation, acting as a positive moderator in this relationship. Nonexecutive directors bridge external drivers of innovation and internal strategic capacities, fostering the adoption of eco-innovation while ensuring it aligns with national objectives and stakeholder expectations.

4.6 | Robustness Checks

To ensure that our results are robust, we run several robustness checks.

4.6.1 | Propensity Score Matching (PSM) and Entropy Balancing

To mitigate endogeneity, we use propensity score matching (PSM) and entropy balancing. PSM helps reduce selection bias by creating balanced treatment and control groups based on observed covariates, thereby mimicking random assignment and enabling more accurate treatment effect estimation (Rosenbaum and Rubin 1983; Austin 2011). However, PSM can be inefficient if unmatched units are discarded and may struggle to achieve perfect covariate balance, especially when the covariate distributions between groups differ significantly.

In contrast, entropy balancing directly reweights the control group to match the treatment group on covariate means, and optionally higher moments like variances, ensuring exact covariate balance and retaining all observations (Hainmueller 2012). This method is particularly useful when sample sizes are limited or when matching is difficult. It avoids both data loss and model dependence, which can arise with PSM.

TABLE 2 | Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1. Eco-innovation	1.000												
2. National innovation system	0.054***	1.000											
	(0.000)												
3. Board size	0.235***	−0.173***	1.000										
	(0.000)	(0.000)											
4. Board gender diversity	0.046***	0.153***	0.014	1.000									
	(0.000)	(0.000)	(0.085)										
5. Nonexecutive directors	−0.062***	0.180***	−0.051***	0.398***	1.000								
	(0.000)	(0.000)	(0.000)	(0.000)									
6. CEO duality	0.036***	0.109***	0.040***	−0.016***	−0.027***	1.000							
	(0.000)	(0.000)	(0.000)	(0.048)	(0.001)								
7. Firm size	0.402***	−0.086***	0.468***	0.058***	−0.018***	0.115***	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)	(0.029)	(0.000)							
8. Return on assets	0.013	−0.060***	0.038***	0.102***	0.069***	0.050***	0.166***	1.000					
	(0.120)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
9. Leverage	0.086***	−0.024***	0.128***	0.052***	0.096***	0.028***	0.243***	−0.114***	1.000				
	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)					
10. Free float	0.142***	0.412***	−0.027***	0.134***	0.054***	0.121***	0.050***	−0.018***	0.027***	1.000			
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.028)	(0.001)				
11. Research and development	−0.096***	0.222***	−0.166***	0.004	0.054***	0.016***	−0.287***	−0.418***	−0.136***	0.158***	1.000		
	(0.000)	(0.000)	(0.000)	(0.583)	(0.000)	(0.045)	(0.000)	(0.000)	(0.000)	(0.000)			
12. Cash holdings	−0.089***	0.150***	−0.112***	−0.112***	−0.097***	0.035***	−0.237***	−0.200***	−0.205***	0.085***	0.391***	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
13. World governance indicator	0.156***	0.567***	−0.116***	0.156***	0.047***	0.027***	−0.032***	−0.053***	−0.076***	0.475***	0.153***	0.035***	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE 3 | The effect of the national innovation system on eco-innovation.

	(1)	(2)
	Eco-innovation	**Eco-innovation**
National innovation system (PCA)	**−0.480****	**−0.550****
	(−2.114)	**(−2.380)**
Board size		−0.007
		(−0.084)
Board gender diversity		0.088***
		(3.542)
Nonexecutive directors		−0.001
		(−0.029)
CEO duality		−0.796
		(−1.604)
Firm size		2.251***
		(4.459)
Return on assets		−8.680***
		(−2.892)
Leverage		0.143
		(0.072)
Free float		0.027
		(1.404)
Research and development		−3.522
		(−0.302)
Cash holdings		2.346
		(0.965)
Worldwide governance indicator		1.382
		(0.577)
Constant	32.188***	−21.407*
	(255.349)	(−1.874)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Observations	14,654	14,654
Adjusted R-squared	0.779	0.779

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

Both methods effectively address confounding from observable characteristics, but they differ in implementation and performance. PSM is more traditional and interpretable, offering clear covariate comparisons, whereas entropy balancing provides superior accuracy and efficiency, particularly in smaller or imbalanced samples. The choice between them ultimately depends on the study context, data characteristics, and the importance of achieving precise covariate balance.

TABLE 4 | The effect of three individual national innovation system characteristics on eco-innovation.

	(1)
	Eco-innovation
Quality of research institutions	**−3.003***** **(−2.984)**
University–industry collaboration	**2.747**** **(2.447)**
Government procurement of high-tech products	**−1.562**** **(−2.238)**
Board size	−0.007 (−0.079)
Board gender diversity	0.089*** (3.585)
Nonexecutive directors	0.004 (0.245)
CEO duality	−0.895* (−1.799)
Firm size	2.162*** (4.267)
Return on assets	−8.593*** (−2.863)
Leverage	0.056 (0.028)
Free float	0.027 (1.381)
Research and development	−4.356 (−0.374)
Cash holdings	2.567 (1.056)
Worldwide governance indicator	1.978 (0.823)
Constant	−11.353 (−0.963)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,654
Adjusted R-squared	0.779

Note: The national innovation system includes three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

TABLE 5 | Interaction with the environment management team.

	(1)
	Eco-innovation
National innovation system (PCA) * Environment management team	**0.514**** **(1.970)**
Environment management team	**6.166***** **(12.344)**
National innovation system (PCA)	**−0.796***** **(−3.024)**
Board size	−0.024 (−0.267)
Board gender diversity	0.091*** (3.595)
Nonexecutive directors	−0.005 (−0.258)
CEO duality	−0.740 (−1.473)
Firm size	1.816*** (3.516)
Return on assets	−11.170*** (−3.601)
Leverage	−0.091 (−0.045)
Free float	0.024 (1.204)
Research and development	−11.062 (−0.926)
Cash holdings	1.267 (0.507)
Worldwide governance indicator	−0.300 (−0.121)
Constant	−11.585 (−0.987)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,009
Adjusted R-squared	0.782

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

TABLE 6 | Interaction with board independence.

	(1)
	Eco-innovation
National innovation system (PCA) * Nonexecutive board members	**0.012****
	(2.206)
National innovation system (PCA)	**−1.518*****
	(−3.061)
Board size	−0.014
	(−0.158)
Board gender diversity	0.087***
	(3.499)
Nonexecutive directors	0.005
	(0.285)
CEO duality	−0.831*
	(−1.675)
Firm size	2.237***
	(4.432)
Return on assets	−8.540***
	(−2.844)
Leverage	0.190
	(0.096)
Free float	0.027
	(1.368)
Research and development	−3.383
	(−0.290)
Cash holdings	2.445
	(1.006)
Worldwide governance indicator	1.977
	(0.821)
Constant	−22.096*
	(−1.933)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,654
Adjusted R-squared	0.779

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) Government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

In our study, we divide the sample into quartiles based on the NIS score, assigning the highest scores to the top quartile, which we define as the treatment group. For each firm in this group, we find the nearest match from the rest of the sample using 11 distinct firm characteristics from our regression analysis. This method ensures that the treatment and control firms are nearly identical in all observable aspects, except for the NIS score. The PSM and entropy balancing results are shown in Models 1 and 2, respectively, in Table A3. The NIS still carries a negative and significant coefficient, suggesting that our conclusion is robust.

Table A4 presents diagnostic testing results for the PSM procedure. Column 1 shows the differences in covariates between firms with strong national innovation systems (the treatment group) and the rest of the sample (the control group) before matching. Column 2 reports the same differences after matching.

Prior to matching, the treatment and control groups differed significantly across several dimensions. For example, firms in the treatment group have smaller boards (Board Size, coefficient $= -0.068$, $t = -3.947$), are more likely to have CEO duality (coefficient $= 1.101$, $t = 5.566$), and tend to have higher leverage, higher R&D spending, greater cash holdings, and greater free float, and are headquartered in countries with stronger governance environments—all statistically significant at conventional levels. These differences suggest non-random assignment into the treatment group and underscore the importance of correcting for selection bias.

After applying PSM, the differences between the treatment and control groups become statistically indistinguishable across all covariates. None of the post-matching coefficients in Column 2 are statistically significant, indicating that the matching process successfully balanced the observable characteristics between the two groups. This suggests that the PSM procedure effectively creates a valid counterfactual group, strengthening the credibility of any subsequent causal inference.

Additionally, Figure 2 shows the density distribution of propensity scores for the treatment and control groups, both before and after matching. Before matching, the distributions differ significantly between the two groups. However, after matching, the distributions are nearly identical, indicating that our matching process is successful (Figure 2).

Change regression: Moreover, we run additional analysis using changes in the variables rather than levels. Running a regression using changes in variables is advantageous because it controls for unobserved heterogeneity and reduces spurious correlations, providing more accurate estimates of causal effects. This method addresses issues of stationarity and autocorrelation, enhancing the reliability of results (Baltagi 2008). It also highlights short-term impacts and trends that may be missed when examining levels (Stock and Watson 2014). The regression result, presented in Table A5, indicates that the coefficient of the NIS is still negative and significant.

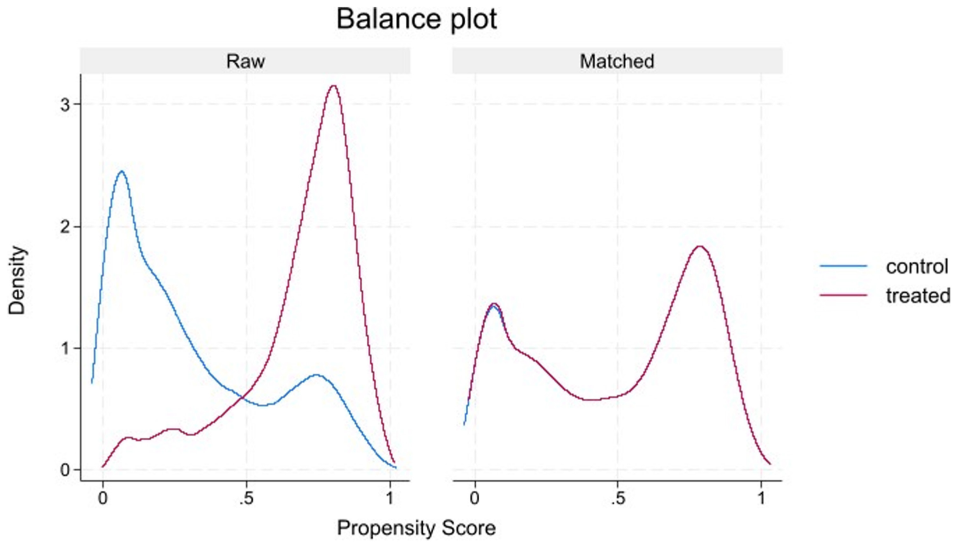

FIGURE 2 | Balance plot.

Alternative sample: It may be argued that the results are driven by US firms, which account for the largest portion of the sample.[9] To ensure robustness, we exclude US firms and rerun the regression analysis. The results, shown in Table A6, remain consistent. Even after various robustness checks, our findings remain similar.

Clustering standard errors: As a robustness check, we cluster standard errors by firm, year, and country to account for potential intra-group correlation across multiple dimensions. Clustering adjusts for dependencies within clusters and leads to more reliable inference (Cameron and Miller 2015; Abadie et al. 2023). However, clustering has its own limitations—such as sensitivity to the number of clusters and inflated standard errors in certain cases (Angrist and Pischke 2009; Thompson 2011)—so we report these results only as a robustness check. Table A7 reports that the results still hold after clustering standard errors showing that NIS is negatively associated with eco-innovation.

Further tests: We conducted further tests with three individual indicators of the NIS to explore further evidence between NIS, eco-innovation, and upper echelon (Table A8). First, we ran the moderation model interacting environmental management team and the indicators of NIS and found that the interaction term of University–industry collaboration * Environmental management team has a significant positive coefficient, whereas Quality of research institutions * Environmental management team has a significant negative coefficient, and Government procurement of high-tech products * Environmental management team has an insignificant coefficient. Hence, these results imply that the environmental team has a complementary relationship with university–industry collaboration but a substitutive relationship with the quality of research institutions in stimulating ecological innovation.

Furthermore, in Table A9, the interaction of board independence with three indicators of NIS revealed that none of the interactions is significant despite the interaction of NIS * Nonexecutive board members in Table 6 is significant. Although this finding is surprising, it suggests some implications. One possible explanation for the significant interaction in Table 6 is that board independence is more likely to influence eco-innovation when it interacts with the entire innovation ecosystem rather than with isolated elements. Board independence might be most effective when responding to a comprehensive innovation environment, which is better captured by the composite NIS index rather than its fragmented parts. This suggests that board independence as a governance mechanism responds more robustly when aligned with an integrated innovation system rather than reacting to individual, narrowly focused innovation initiatives.

Additionally, there may be a dilution of effects when the NIS is broken down into its components. Each of these components, when examined separately, may lack the statistical power to drive significant interactions with board independence. The holistic measure, however, encapsulates the cumulative effect that aligns better with the strategic decisions made by independent boards. This indicates that the relationship between board independence and eco-innovation is complex and multifaceted, likely requiring a comprehensive and multidimensional innovation environment to manifest significantly.

In conclusion, the discrepancy between Table 6 and Table A9 results from the difference between a holistic, integrated measure and isolated components of the NIS. The composite index reflects the broader innovation ecosystem, where board independence can significantly enhance eco-innovation. In contrast, the fragmented view in Table A9 fails to capture this synergy, leading to nonsignificant interaction terms. This suggests that board independence is more effective when aligned with a comprehensive national innovation environment rather than when responding to individual, isolated innovation factors.

5 | Conclusions

In the face of growing ecological concerns arising from pollution and climate change, there is an increasing interest among researchers to suggest viable solutions to organizations for a cleaner environment. This trend underscores the importance of eco-innovation, which implies transforming traditional operation processes towards more eco-friendly practices and developing eco-friendly processes and products. So far, numerous studies have focused on whether firm financial and governance attributes foster eco-innovation; however, institutional contexts are of critical importance for policymaking and laying out essential conditions. Hence, we focus on whether the NIS cultivates firms' eco-innovation commitment. Further, we deepen our investigation by exploring two corporate channels in creating a synergy between the NIS and firms' eco-innovation namely the environmental management team and nonexecutive directors.

We find that composite NIS proxy is negatively associated with eco-innovation. Given that this was a bit surprising and contrary to expectations, we expanded our investigation on three pillars of composite NIS proxy. The results indicate that whereas the quality of research institutions and government procurement of high-tech products are still negatively associated with eco-innovation, university–industry collaboration is positively associated with it. Further investigation reveals that the environmental management team and nonexecutive directors are two channels via which NIS reinforces firms' eco-innovation capacity. However, readers should also consider that environmental management teams have sometimes complementary but sometimes substitutive relationships with NIS indicators to draw correct inferences. Lastly, it is notable that board independence is most effective when responding to a comprehensive innovation environment, which is better captured by the composite NIS index rather than its fragmented parts.

6 | Discussions and Implications

Our study provides evidence for the institutional theory's relevancy in stimulating or hindering eco-innovation (DiMaggio and Powell 1983; Scott 1995). More specifically, coercive forces (i.e., government high-tech procurement) do not support eco-innovation, but normative forces (i.e., university–industry collaboration) do. The collaboration between universities and industries helps transfer knowledge and innovative capabilities (Perkmann et al. 2013), commercialize academic knowledge, and create patenting (e.g., eco-products and eco-processes) (Rybnicek and Königsgruber 2019). We also provide evidence for the positive interplay between institutional and upper-echelon theories such that environmental team organization and board configuration with nonexecutive directors help create a synergy between NIS and eco-innovation. It is evident that environmental teams with their specialized knowledge and dedication to sustainability align external policies with firms' strategic goals and capabilities (Scarpellini et al. 2020; Valero-Gil et al. 2023). Nonexecutive directors are also an important dimension of board social capital in reaching out to external resources and facilitating the transfer and absorption of new knowledge and technologies (Barroso-Castro, Villegas-Periñan, and Casillas-Bueno 2016; Ceipek et al. 2021).

Our findings suggest that the NIS requires a new configuration to alleviate environmental concerns through eco-innovation. It appears that government high-tech procurement does not involve an ecological perspective, and research institutions per se do not focus on eco-innovation sufficiently. Growingly, environmental concerns and climate change issues are becoming one of the most dominant issues around the globe, the government and research institutions may prioritize contributing to exploring eco-friendly solutions. It is hoped that firms will be encouraged to incorporate eco-friendly practices in their operations if institutional support is provided more profoundly.

On the other hand, what is good is that university–industry collaboration induces greater eco-innovation engagement via bridging theory and practice. This finding suggests greater collaboration between universities and firms, which may help researchers implement what they formulate and facilitate firms' transformation to cutting-edge technologies for eco-products and processes. In creating a synergy between the NIS and eco-innovation, we find that the environmental management team and nonexecutive directors are useful channels. This supports the stakeholder theory such that the environmental team and nonexecutive directors strive to transform the operational process to address stakeholders' environmental concerns by leveraging institutions' support for eco-innovation. This finding has implications for environmental management design and board configuration.

Our investigation has several limitations. First, our sample is unbalanced across countries due to the differing number of observations affiliated with countries in the data source. Second, the sample is confined to 2007–2018 due to the availability of national innovation system data for those years. After 2018, the World Economic Forum changed the metrics that it publishes in the Global Competitiveness Index. Third, the data for the environmental management team is binary due to the unavailability of continuous data. Upon our investigation, future studies could expand the investigation. They can focus on other corporate and institutional characteristics that might drive firm eco-innovation. For instance, investigating how institutional ownership affects the NIS-eco-innovation connection or whether environmental regulations such as imposing environmental taxes or regulations might change the NIS–eco-innovation link deserves to be the focus of future studies. Furthermore, the NIS–eco-innovation connection might vary in shareholder-oriented versus stakeholder-oriented countries as the former prioritizes shareholders' interests, whereas the latter prioritizes the interests of more encompassing stakeholders. Moreover, other than formal institutions, the impact of informal institutions should not be ignored. In this respect, integrating the national culture into our model would reveal interesting results to explore how the NIS–eco-innovation connection changes in masculinity/femininity, long-horizon/short-horizon, and indulgence versus restraint societies, among others. In addition, financial resource availability might be also of critical importance in leveraging NIS for eco-innovation, which could be a potential future investigation. Finally, future research could delve deeper into why and where two dimensions of the NIS weaken firms' eco-innovation. To answer these questions, qualitative studies and/or regional and contextual empirical studies could be conducted. Such a study might also investigate and highlight how NIS can be better reformulated in such a way that it supports eco-innovation.

Endnotes

[1] Please see the wider description of eco-innovation in the "Variables" section and Table A1.

[2] The World Economic Forum changed its formulation of the competitiveness index after 2018, so no more of these three proxies are measured in the index.

[3] We explain in the following section which data we collected from which source.

[4] Please see the sample distribution across countries in Table A2.

[5] Environmental, social, and governance.

[6] It is publicly available data retrievable from Home | Worldwide Governance Indicators (worldbank.org).

[7] To ensure that multicollinearity is not an issue, we calculate the variance inflation factor (VIF) for each variable. All VIF values are below 2.0, indicating that multicollinearity is not a concern.

[8] It can be calculated as follows: one standard deviation of NIS (PCA), which is 1.52 multiplied by the coefficient of NIS in Table 3 Model 2, which is 0.550. The result is 0.836. Then, we have it divided by the standard deviation of eco-innovation, which is 32.29. The result is 2.59.

[9] Please see Table A2.

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Appendix

TABLE A1 | Variable descriptions.

Variables	Definitions
Eco-innovation	The environmental innovation score reflects a company's capacity to create new market opportunities through new environmental technologies and processes or eco-designed products (score ranges between 0 and 100). Eco-innovation score is drawn on 20 metrics, namely, eco-labeled product development, fuel consumption, noise-reducing product development, hybrid vehicle development, environmental screening criteria in investments, total fleet's average CO_2 emissions, the percentage of labeled wood or forest products (e.g., Forest Stewardship Council) from total wood or forest products, organic food development, production and distribution of agrochemicals, nuclear energy production percentage, product or technology development for use in the clean, product or technology development for water use efficiency, renewable energy, product or service development for energy efficiency of buildings, total amount of environmental R&D costs, the company's commitment to the Equator Principles, leasing or marketing buildings that are certified by recognized real estate certifications, revenue from environmental products and services, recycling program commitment, and public commitment to divest from fossil fuel (some indicators are sector specific like hybrid vehicle development)
Quality of research institutions	Response to the survey question, "In your country, how do you assess the quality of scientific research institutions?" [1 = *extremely poor*; 7 = *extremely good*] (WEF 2018)
University–industry collaboration	Response to the survey question "In your country, to what extent do businesses and universities collaborate on research and development?" [1 = *do not collaborate at all*; 7 = *collaborate extensively*] (WEF 2018)
Government procurement of high-tech products	Response to the survey question "In your country, to what extent do government purchasing decisions foster innovation?" [1 = *not at all*; 7 = *to a great extent*] (WEF 2018)
National innovation system (PCA)	Principal component analysis of above three indicators of national innovation system namely quality of research institutions, university–industry collaboration, and government procurement of high technology products
Environment management team	Existence of an environmental management team in the company. The team could be an individual or committee performing the functions directed to environmental issues and composed of employees of the company, who are operational on a day-to-day basis and are not the board committees (directors)
Board size	Number of directors on board
Board gender diversity	Female directors' proportion on board
Nonexecutive directors	Nonexecutive directors' proportion on board
CEO duality	CEO duality showing if the CEO and chair positions are held by the same person
Firm size	Natural logarithm of total assets
Return on assets	Earnings before interest and tax scaled by total assets
Leverage	Total debt scaled by total assets
Free float	Free float percentage of shares
Research and development	Research and development expenditures scaled by total assets
Cash holding	Cash and cash equivalents scaled by total assets
Worldwide Governance Indicators	The average of six Worldwide Governance Indicators, namely, control of corruption, political stability and absence of violence/terrorism, government effectiveness, voice and accountability, regulatory quality, and rule of law (Score ranges between −2.5 and 2.5). The data were retrieved from the World Bank

TABLE A2 | Sample distribution by country.

Country	Frequency	Percent	Cumulative
Argentina	37	0.25	0.25
Australia	361	2.41	2.66
Austria	69	0.46	3.12
Belgium	98	0.65	3.77
Brazil	181	1.21	4.98
Canada	298	1.99	6.97
Chile	59	0.39	7.37
China	745	4.98	12.34
Colombia	23	0.15	12.5
Denmark	168	1.12	13.62
Egypt	28	0.19	13.8
Finland	163	1.09	14.89
France	332	2.22	17.11
Germany	442	2.95	20.06
Greece	48	0.32	20.38
Hong Kong	245	1.64	22.02
Hungary	20	0.13	22.15
India	385	2.57	24.72
Indonesia	91	0.61	25.33
Ireland; Republic of	191	1.28	26.61
Israel	55	0.37	26.98
Italy	115	0.77	27.74
Japan	2291	15.3	43.04
Korea; Republic (S. Korea)	509	3.4	46.44
Kuwait	4	0.03	46.47
Luxembourg	37	0.25	46.72
Malaysia	67	0.45	47.16
Mexico	127	0.85	48.01
Netherlands	164	1.1	49.11
New Zealand	27	0.18	49.29
Norway	76	0.51	49.8
Oman	4	0.03	49.82
Pakistan	2	0.01	49.84
Peru	31	0.21	50.04
Philippines	26	0.17	50.22
Poland	28	0.19	50.4
Portugal	17	0.11	50.52
Qatar	12	0.08	50.6
Russia	47	0.31	50.91
Saudi Arabia	34	0.23	51.14
Singapore	106	0.71	51.85
Slovenia	2	0.01	51.86
South Africa	185	1.24	53.1
Spain	96	0.64	53.74
Sweden	297	1.98	55.72
Switzerland	411	2.74	58.47
Taiwan	799	5.34	63.8
Thailand	71	0.47	64.28
Turkey	101	0.67	64.95
Ukraine	9	0.06	65.01
United Kingdom	752	5.02	70.03
United States of America	4478	29.91	99.94
Zimbabwe	9	0.06	100
Total	14,973	100.00	

(Continues)

TABLE A2 | (Continued)

TABLE A3 | Propensity score matching and entropy balancing.

	Propensity score matching	Entropy balancing
	(1)	(2)
	Eco-innovation	Eco-innovation
National innovation system (PCA)	**−0.772****	**−0.609*****
	(−2.361)	**(−2.801)**
Board size	0.338*	0.306**
	(1.717)	(2.316)
Board gender diversity	0.089**	0.115***
	(2.382)	(4.460)
Nonexecutive directors	−0.047	−0.040
	(−1.178)	(−1.463)
CEO duality	−0.979	−2.178***
	(−1.098)	(−3.577)
Firm size	0.972	2.011***
	(1.217)	(3.843)
Return on assets	2.469	−8.195***
	(0.604)	(−2.937)
Leverage	−5.149*	−5.650***
	(−1.912)	(−3.105)
Free float	0.019	0.037*
	(0.576)	(1.666)
Research and development	−4.831	−8.823
	(−0.329)	(−0.881)
Cash holdings	−1.714	0.015
	(−0.520)	(0.007)
Worldwide governance indicator	−8.214	0.591
	(−1.308)	(0.135)
Constant	20.125	−16.249
	(1.028)	(−1.247)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Observations	6678	14,654
Adjusted R-squared	0.781	0.766

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.

***$p < 0.01$.

**$p < 0.05$.

*$p < 0.1$.

TABLE A4 | Diagnostic testing for propensity score matching (PSM).

	(1)	(2)
	Treatment (Strong national innovation system)	**Treatment (Strong national innovation system)**
	Pre-match	**Post-match**
Board size	−0.068***	0.028
	(−3.947)	(1.074)
Board gender diversity	−0.005	−0.000
	(−0.738)	(−0.010)
Nonexecutive directors	0.047***	0.002
	(9.484)	(0.227)
CEO duality	1.101***	−0.083
	(5.566)	(−0.683)
Firm size	−0.097	−0.012
	(−0.906)	(−0.084)
Return on assets	0.982	0.064
	(1.428)	(0.111)
Leverage	1.514***	−0.195
	(3.120)	(−0.294)
Free float	0.027***	−0.001
	(5.906)	(−0.417)
Research and development	3.414***	0.561
	(3.899)	(0.712)
Cash holdings	2.290***	−0.144
	(3.007)	(−0.509)
World governance indicator	0.581***	−0.125
	(4.678)	(−0.108)
Constant	−6.005**	0.191
	(−2.548)	(0.038)
Pseudo R-squared	0.255	0.001
Observations	14,973	7614

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE A5 | Regression based on changes in the variables.

	(1)
	Eco-innovation
Δ National innovation system (PCA)	**−0.490****
	(−2.237)
Δ Board size	−0.035
	(−0.403)
Δ Board gender diversity	0.069**
	(2.436)
Δ Nonexecutive directors	−0.008
	(−0.447)
Δ CEO duality	−0.938*
	(−1.911)
Δ Firm size	0.722
	(1.034)
Δ Return on assets	1.420
	(0.478)
Δ Leverage	0.678
	(0.294)
Δ Free float	0.050**
	(2.329)
Δ Research and development	−3.706
	(−0.303)
Δ Cash holdings	5.169**
	(2.315)
Δ Worldwide governance indicator	2.632
	(0.763)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Constant	1.796***
	(13.282)
Observations	12,184
R-squared	0.099

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. t-statistics in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE A6 | Excluding US firms.

	(1)
	Eco-innovation
National innovation system (PCA)	**−0.840*****
	(−2.740)
Board size	−0.029
	(−0.306)
Board gender diversity	0.097***
	(3.424)
Nonexecutive directors	0.009
	(0.493)
CEO duality	−0.223
	(−0.407)
Firm size	2.627***
	(4.432)
Return on assets	−10.449***
	(−2.777)
Leverage	5.699**
	(2.226)
Free float	0.029
	(1.349)
Research and development	3.879
	(0.246)
Cash holdings	6.109**
	(2.015)
Worldwide governance indicator	1.824
	(0.724)
Constant	−30.950**
	(−2.336)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	10,220
Adjusted R-squared	0.789

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE A7 | Clustering standard errors.

	Eco-innovation
National innovation system (PCA)	**−0.705***
	(−1.677)
Board size	0.349**
	(2.184)
Board gender diversity	0.075*
	(1.935)
Nonexecutive directors	−0.013
	(−0.462)
CEO duality	−1.769*
	(−1.930)
Firm size	1.624**
	(2.236)
Return on assets	−8.630**
	(−2.110)
Leverage	−3.517
	(−1.162)
Free float	0.031
	(1.052)
Research and development	−15.661
	(−0.995)
Cash holdings	3.797
	(1.042)
Worldwide governance indicator	−7.045
	(−1.311)
Constant	1.706
	(0.097)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,684
Adjusted R-squared	0.805

Note: National innovation system (PCA) is a combined index from a principal component analysis based on three individual characteristics: (1) quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE A8 | The interactions of NIS indicators with the environment management team.

	Eco-innovation
Quality of research institutions*Environmental management team	**−5.023****
	(−2.628)
University–industry collaboration*Environmental management team	**5.307****
	(2.687)
Government procurement of high-tech products*Environmental management team	**0.704**
	(0.408)
Environmental management team	3.910
	(1.132)
Quality of research institutions	−0.029
	(−0.016)
University–industry collaboration	−0.320
	(−0.181)
Government procurement of high-tech products	−1.901
	(−1.568)
Board size	−0.011
	(−0.139)
Board gender diversity	0.094**
	(2.266)
Nonexecutive directors	0.002
	(0.152)
CEO duality	−0.940
	(−1.154)
Firm size	1.720**
	(2.552)
Return on assets	−10.641**
	(−2.531)
Leverage	−0.284
	(−0.071)
Free float	0.025
	(0.830)
Research and development	−12.193
	(−0.843)
Cash holdings	1.459
	(0.336)
Worldwide governance indicator	0.010
	(0.003)
Constant	−0.722
	(−0.047)

(Continues)

TABLE A8 | (Continued)

	Eco-innovation
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,009
Adjusted R-squared	0.781

Note: (1) Quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products are three individual characteristics of the national innovation system. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

TABLE A9 | The interactions of NIS indicators with the nonexecutive board members.

	Eco-innovation
Quality of research institutions*Nonexecutive board members	0.058
	(1.264)
University-industry collaboration*Nonexecutive board members	−0.032
	(−0.792)
Government procurement of high-tech products*Nonexecutive board members	−0.009
	(−0.297)
Environmental management team	6.110***
	(3.553)
Quality of research institutions	−7.311*
	(−1.981)
University–industry collaboration	4.992
	(1.492)
Government procurement of high-tech products	−0.788
	(−0.290)
Board size	−0.027
	(−0.329)
Board gender diversity	0.089**
	(2.664)
Nonexecutive directors	−0.110
	(−1.000)
CEO duality	−0.920
	(−1.071)
Firm size	1.665**
	(2.451)
Return on assets	−10.839**
	(−2.446)
Leverage	−0.176
	(−0.048)
Free float	0.025
	(0.816)
Research and development	−12.198
	(−0.854)
Cash holdings	1.455
	(0.338)
Worldwide governance indicator	1.665
	(0.533)
Constant	7.007
	(0.407)
Year fixed effects	Yes
Firm fixed effects	Yes
Country fixed effects	Yes
Observations	14,009
Adjusted R-squared	0.781

Note: (1) Quality of scientific research, (2) university–industry collaboration, and (3) government procurement of advanced technology products are three individual characteristics of the national innovation system. All variables are defined in Table A1. *t*-statistics in parentheses.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.