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Exploring the effect of R&D support, green technology transfer, sustainable innovation

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Abstract

This article investigates the impact of R&D support on sustainable innovation through the mediating role of green technology transfer. Based on our analysis of data from 220 firms in Vietnam, we find the following: (1) R&D support has a positive impact on green technology transfer, (2) green technology transfer mediates the relationship between R&D support and sustainable innovation, and (3) The influence of green technology transfer on sustainable innovation is heightened in the presence of a firm's commitment to environmental ethics. These findings underline the critical role of government R&D funding in shaping sustainable innovation in emerging markets. The findings further show the crucial role of environmental commitment as a moderating factor in green technology transfer contexts. Managing the interaction between green technology transfer and a firm's commitment to environmental ethics is essential to optimize the benefits of sustainable innovation. This study offers practical insights for firms seeking to improve their sustainable innovation outcomes.

KEYWORDS
government R&D funding, green technology transfer, innovation, R&D support, sustainable development

1 | INTRODUCTION

The ability of firms to report environmental, social, and governance (ESG) metrics has become an essential requirement for firms. Indeed, a widely held consensus is that global imbalances in social, economic, and environmental realms have escalated to a degree where maintaining the status quo of unrestricted economic activities is no longer feasible (Reficco et al., 2018). As we confront global issues such as climate change, poverty, and inequality, the principles of sustainable development become critical for envisioning a future where humanity coexists harmoniously with the planet, leaving a positive legacy for generations to come. Previous studies have suggested that the urgency to instigate changes in line with the requirements of sustainable development has given rise to the field of sustainable innovation (Reficco et al., 2018; Schaltegger et al., 2015).

Consequently, firms in various sectors are sharing their strategies to achieve net-zero goals, particularly focusing on assessing individual manufacturers among their suppliers (Healey et al., 2021; Rissman et al., 2020). As environmental reporting edges closer to becoming obligatory, enhancing transparency with customers, consumers, investors, and employees through improving products is considered imperative for achieving success (Dong et al., 2014; Moon, 2007). Sustainable innovation is considered as an innovation that enhances sustainability performance across ecological, economic, and social dimensions (Boons et al., 2013). Stated differently, sustainable innovation involves the enhancement of products to envision a better and more sustainable future for customers and the environment. When firms develop new products, they typically focus on designing to meet a defined set of predetermined criteria. However, sustainable innovation takes shape when environmental sustainability becomes a central factor influencing how a product is conceived, crafted, and maintained throughout its lifecycle (Adomako, 2020; Adomako & Nguyen, 2023).

The prevailing literature underscores the important role of intensive research and development (R&D) efforts in infusing sustainability principles into existing socio-technical systems (Sarpong et al., 2023; Shao et al., 2021). Nevertheless, concerns persist regarding the limited and delayed impact or returns on investment from R&D efforts, leading to a sustained reduction in expenditure (Becker, 2015; Bhattacharya & Packalen, 2020). In particular, governments across the globe have demonstrated their commitment to supporting various industries through R&D support (Adomako, Amankwah-Amoah, Debrah, et al., 2021; Jiang et al., 2023; Kang & Park, 2012). This support for R&D can significantly contribute to the development of sustainable innovation. The support for R&D entails providing financial assistance to firms engaged in research and development activities, serving as a crucial input for the sustainable innovation process.

Despite this insight, we still have a limited understanding of how and when R&D support yields sustainable innovation in firms. For example, although significant efforts have been devoted to understanding the antecedents and outcome of sustainable innovation (Adomako, 2020; Adomako & Nguyen, 2023), there remains a lack of clarity regarding how government R&D funding or support intersects with sustainable innovation and the mechanisms through which R&D support may shape sustainable innovation. Moreover, there's a notable dearth of research focusing on how R&D support drives SMEs, particularly those in emerging markets, to engage in sustainable innovation activities. Consequently, this article aims to investigate the impact of R&D support on sustainable innovation through the mediating mechanism of green technology transfer and to elucidate the contextual factors influencing this potential relationship. Given that firms worldwide are taking steps to mitigate environmental challenges by embracing environmental responsibilities and enhancing their sustainable innovation endeavors (Martinez et al., 2019), understanding how R&D support improves sustainable innovation is critical.

This article contributes to the literature in three ways. First, we demonstrate that R&D support in the form of government funding significantly enhances sustainable innovation. While previous research has advocated the need to consistently invest in R&D to unlock more advanced and sustainable innovations (Sarpong et al., 2023; Xu et al., 2021), it remains a myriad for governmental bodies to enhance investment in R&D to improve sustainable innovation. In this study, we show the potentially positive impact that such investment in R&D can have on overall sustainable innovation. Second, we expand the existing research by illustrating how R&D support, when combined with a firm's commitment to environmental ethics (Muller & Kolk, 2010; Wang et al., 2018), can amplify sustainable innovation. Thus, we highlight the important role of environmental commitment in this process. Finally, we enrich the literature by delving into the intricate mechanism between R&D support and sustainable innovation. In particular, we introduce green technology transfer as a mediating mechanism in this relation. Therefore, this article contributes to our understanding of the mechanisms by which R&D support influences sustainable innovation through green technology transfer (Gopalakrishnan & Santoro, 2004; Jiang et al., 2023). By delving into this relationship, we expand the current body of knowledge by elucidating the pathways through which R&D support influences sustainable innovation.

We structure the remainder of the article as follows: we begin with an exposition of the theoretical underpinnings of this study, followed by the development of our hypotheses. Subsequently, we elucidate our sample and detail our data collection procedures. The subsequent section presents the data analysis and results. Finally, we discuss the implications of our findings and suggest future research directions.

2 | THEORETICAL BACKGROUND AND HYPOTHESES

2.1 | Resource-based theory and sustainable innovation

The Resource-Based Theory (RBT) suggests that a firm's resources and capabilities play a central role in achieving sustainable competitive advantage and superior performance (Barney et al., 2011; McWilliams & Siegel, 2011). In this study, we argue that RBT emphasizes the identification of critical resources and capabilities within a firm. These resources include government funding for R&D, expertise in green technology, access to sustainable innovation practices, and established networks for technology transfer. First, sustainable innovation produced by firms can confer sustainable competitive advantages, including reduced manufacturing costs (Han et al., 2019), a positive brand perception by customers (Olsen et al., 2014), and enhanced compliance with regulatory standards (Khanra et al., 2022). However, effectively utilizing sustainable innovation as a strategic resource often necessitates mechanisms for knowledge transfer driven by buyers and the acquisition of knowledge capabilities within the firm. Additionally, it requires investments in research and development (Duque-Grisales et al., 2020), and an established technological capability (Forcadell et al., 2021). Second, RBT envisions a firm as a reservoir of resources and capabilities, granting a sustainable advantage over competitors and delivering superior performance (Barney, 1991; Barney et al., 2001). The firm can sustain this competitive advantage when these resources and capabilities are valuable, rare, not easily imitated, and not substitutable (Barney, 1991). Thus, the central tenet of RBT is the attainment of sustainable competitive advantage through unique and valuable resources. Applying this logic in the current study, we suggest that it involves assessing how R&D support and effective green technology transfer can lead to sustained competitive advantages, like cost efficiency, market positioning, or superior sustainable innovations. In addition, RBT emphasizes how resources can be complementary and integrated to create synergies. In this context, we argue that it is important to assess how R&D support can complement a firm's existing resources and capabilities, and how this integration can enhance the effectiveness of green technology transfer and sustainable innovation.

2.2 | Government R&D support and green technology transfer

In this study, we hypothesize that R&D support would predict green technology transfer. R&D support entails the degree of a firm's engagement with government funding such as government grants (Kang & Park, 2012). Considering the advantages stemming from sustainable innovation efforts, governments often provide support to firms in the form of subsidies, tax incentives, and loans to counteract the adverse impact of environmental degradation. In emerging economies, for instance, government-sponsored R&D funding programs have gained increasing significance for fostering innovation. This, in turn, enables local firms to cultivate mutually beneficial partnerships with global buyers. Conversely, advanced economies typically encourage sustainable innovation through grants. In the face of constraints and heightened global competition, businesses seek to capitalize on government R&D support to navigate challenges (Rosenfeld, 1996). Regulatory ambiguities and a lack of market support mechanisms, for instance, can limit firms' access to financial resources required for R&D projects and sustainable innovation development. Therefore, governments actively prompt firms to access R&D project funds to address perceived market shortcomings, alleviate institutional obstacles, and stimulate sustainable innovation (Feldman & Kelley, 2006).

In this study, we suggest that the utilization of government support has the potential to spur green technology transfer. For example, the provision of government subsidies for research has been proven to be a potent public policy tool, particularly in contexts where knowledge spillover is more pronounced (Spence, 1984; Trajtenberg, 2001). First, R&D support provides the necessary financial and technical resources for research and development focused on green technologies. These resources facilitate the creation, improvement, and dissemination of environmentally sustainable technologies. The availability of funds and expertise through R&D support can enhance the efficiency and effectiveness of green technology transfer, ultimately driving a positive relationship between R&D support and the transfer of green technologies.

Second, R&D support encourages knowledge sharing, collaboration, and the exchange of expertise within and across organizations (Adomako, Amankwah-Amoah, Debrah, et al., 2021). This exchange of ideas and expertise is essential for the successful transfer of green technologies. R&D support facilitates the development of specialized knowledge in the field of green technologies, which can then be shared and transferred to other entities interested in adopting or implementing green technologies. Therefore, an increase in R&D support is expected to positively influence the transfer of green technologies.

Third, government policies and incentives often accompany R&D support, aiming to promote the development and adoption of green technologies. These policies may include tax incentives, grants, or subsidies for R&D activities related to green technologies. The alignment of policies and incentives with the goals of green technology transfer provides a conducive environment for technology providers and adopters to engage in transfer activities. As R&D support aligns with these policies and incentives, it fosters a positive relationship with green technology transfer by encouraging investment and collaboration in the development and dissemination of sustainable technologies. Thus, we hypothesize that:

> **H1.** R&D support is positively related to green technology transfer.

2.3 | Mediating role of green technology transfer

Green technology transfer refers to the process of disseminating and adopting environmentally friendly technologies, practices, or innovations from one entity to another (Hou et al., 2023; Steenbergen & Saurav, 2023). These technologies tend to address environmental challenges, reduce resource consumption, minimize pollution, and promote sustainability. The goal is to facilitate the widespread adoption of eco-friendly solutions and promote sustainable development on a global scale. Green technology transfer aligns with the United Nations Sustainable Development Goals, particularly Goal 9 (Industry, Innovation, and Infrastructure) and Goal 13 (Climate Action). This aims at promoting sustainable innovation, and the adoption of clean and efficient technologies to combat climate change. Thus, green technology transfer is a vital mechanism to accelerate the adoption and diffusion of environmentally sustainable technologies and practices, contributing to a more sustainable and greener future for all. Following this assertion, we contend that green technology transfer would serve as a mechanism through R&D support predicts sustainable innovation.

First, R&D support often involves funding and resources to enhance a firm's technological capabilities (Adomako, Amankwah-Amoah, Debrah, et al., 2021; Kang & Park, 2012). This, in turn, is likely to facilitate the development and adoption of green technologies. Thus, the increased technological capacity gained through R&D support acts as a precursor for green technology transfer. Second, we argue that R&D support helps firms to create new green technologies or improve existing ones. When these innovations are shared or transferred between firms, it accelerates the diffusion and adoption of green technologies throughout the industry (Brantnell & Baraldi, 2022; Gopalakrishnan & Santoro, 2004). Green technology transfer thus becomes a critical mechanism for spreading sustainable innovation resulting from R&D efforts. Third, R&D support can facilitate collaboration and partnerships with external entities (Kang & Park, 2012; Schuh et al., 2022), such as research institutions or other firms, which can bring valuable knowledge and expertise in green technologies. The transfer of this external knowledge through collaborative efforts enhances the firm's ability to innovate sustainably, acting as a mediating pathway between R&D support and the adoption of green technologies. Finally, we suggest that R&D support often includes financial assistance and guidance from policymakers, making the implementation of green innovations more cost-effective and efficient. The accessibility of resources through R&D support promotes the smoother transfer and integration of green technologies (Hou et al., 2019), leading to sustainable innovation by reducing barriers and costs associated with the adoption of eco-friendly practices. Therefore, we hypothesize that green technology transfer mediates the relationship between R&D support and sustainable innovation, as the transfer of green technologies plays a crucial role in leveraging R&D efforts for sustainable innovation within firms.

H2. Green technology transfer mediates the relationship between R&D support and sustainable innovation.

2.4 | Moderating role of environmental commitment

A firm's dedication to environmental principles plays a vital role in the realm of environmental management and offers valuable insights into understanding how green technology transfer improves environmental management strategies such as sustainable innovation (Wang et al., 2018; Yen & Yen, 2012). The commitment to environmental values impacts a firm's activities related to green technology transfer. Indeed, firms that strongly prioritize environmental concerns are more inclined to view environmental preservation as an integral part of their corporate social responsibility, demonstrating a keen desire to safeguard the environment (Muller & Kolk, 2010). Instructively, environmental commitment signifies a firm's dedication and alignment of values towards sustainable and eco-friendly practices (Lee & Ball, 2003; Wang et al., 2018). When a firm is deeply committed to environmental causes, it is more likely to perceive green technology transfer as a means to align with its values and objectives for sustainability and environmental responsibility. This suggests that firms with strong environmental commitment will perceive green technology transfer not merely as an economic or technological transaction but as an opportunity to advance their sustainability objectives. Thus, the greater the alignment between the received green technologies and the firm's commitment to sustainability, the stronger the impetus for driving sustainable innovation from the transferred technology.

Additionally, environmental commitment tends to foster the development of an innovation ecosystem within the firm (Oliveira-Duarte et al., 2021; Somjai, 2020) and this is likely to encourage the integration and efficient implementation of transferred green technologies. This ecosystem is likely to catalyze the innovation process and enhance the value and impact of the transferred technologies on sustainability. This suggests that firms with a high level of environmental commitment are more likely to establish an organizational culture that values innovation geared towards sustainability. We argue that green technology transfer, when integrated into this innovation ecosystem, is more effectively assimilated, adapted, and transformed into sustainable innovation, given the organizational dedication to environmental goals.

Finally, firms with a strong environmental commitment are more visible and credible to various stakeholders (Bhatia & Kumar, 2022; Henriques & Sadorsky, 1999), including governmental bodies, investors, and the public. This visibility and credibility attract greater support and resources for implementing innovations resulting from green technology transfer leading to enhanced sustainable outcomes. This indicates that environmental commitment is likely to provide a positive image and reputation for the firm in the eyes of stakeholders who are interested in sustainable practices. When green technology transfer is aligned with this commitment, stakeholders are more likely to support and invest in the innovation derived from these transferred technologies. The higher level of support garnered due to environmental commitment amplifies the impact and effectiveness of sustainable innovation resulting from the green technology transfer. Given these arguments, we hypothesize that:

H3. The relationship between green technology transfer and sustainable innovation is moderated by environmental commitment, such that the greater the degree of environmental commitment, the stronger the relationship between green technology transfer and sustainable innovation.

3 | METHOD

3.1 | Study context

In this research, our focus was on examining our hypotheses within the context of firms in Vietnam. Vietnam stands as a rapidly growing nation in Southeast Asia, presenting a unique backdrop for our study. Particularly, small and medium enterprises (SMEs) in Vietnam operate in a distinctive environment shaped by a variety of factors. The nation has undergone substantial economic growth, transitioning into a market-oriented economy, thus offering both opportunities and challenges for SMEs. A significant aspect of this context is the active support provided by the government to foster SME development through diverse policies and initiatives. Several reforms have been implemented to stimulate innovation including simplifying business registration processes and extending financial support and incentives to SMEs (Adomako & Nguyen, 2023). These initiatives are designed to encourage innovation, job creation, and economic diversification. However, SMEs in Vietnam encounter various challenges, with limited access to finance being a major obstacle. Banks often prioritize lending to larger enterprises, making it difficult for SMEs to secure the necessary capital for business growth and expansion. Despite these hurdles, SMEs in Vietnam exhibit resilience and adaptability, playing a crucial role in employment generation, poverty reduction, and economic development at the grassroots level. Ongoing efforts are being made to address these challenges, including initiatives to promote digitalization and the establishment of support mechanisms such as business incubators and accelerators. Considering the aspects discussed above, Vietnam serves as an ideal setting within Southeast Asia to test our hypotheses.

3.2 | Sample and data collection

Survey-based studies often grapple with limitations such as small sample sizes and reliance on single informants (Adomako, Amankwah-Amoah, Tarba, & Khan, 2021). To address these concerns, we conducted data collection at two distinct time points in

2021 and 2022. Initially, we dispatched a questionnaire to chief executive officers (CEOs) to measure R&D support, green technology transfer, and all relevant control variables. Subsequently, four weeks later, we sent a questionnaire to a member of the top management team to capture data on sustainable innovation and the moderating variable.

Before the main survey, we pre-tested the survey instrument with 11 CEOs (whose data was excluded from this study). Based on their invaluable feedback, we refined the questionnaire to ensure the reliability and sound factor structure of our measures. We utilized the Vietnam Business Directory to randomly select 600 firms operating in Vietnam. The sampling adhered to specific criteria: (1) firms not affiliated with any company group, (2) firms with direct contact details of the CEO or a member of the founding team, (3) firms with a workforce of no more than 250 full-time employees, and (4) manufacturing firms engaged in productive activities.

Out of the 600 firms initially identified, 78 were either closed or untraceable, resulting in 522 viable firms. We have 22 research assistants (data collectors) from a local market research firm. During wave 1, the research assistants visited the headquarters of the 522 firms. We conducted a pen-and-paper survey and obtained data from 243 CEOs. After discarding 20 incomplete surveys, we retained 223 complete responses. Four weeks later, in wave 2, we obtained responses from a senior team member within each firm that had participated in the first wave, yielding 220 matched surveys from both waves. This equated to a response rate of 36.66%. A t-test comparison demonstrated no significant differences between the responding and non-responding firms in terms of size and age. The sample had a mean age of 7.59 years ($SD = 1.20$), with an average size of 45.06 full-time employees ($SD = 11.60$).

3.3 | Measures

We assessed all constructs using a seven-point Likert scale, where 1 indicated “strongly disagree” and 7 indicated “strongly agree”. Table 1 provides complete information regarding these measurements.

3.3.1 | R&D support

A firm's engagement with government R&D support was measured using government grants as an indicator of government investment, following Kang and Park (2012). Similarly, this approach was applied to evaluate government-sponsored R&D support, with the coding scheme being 1 for firms that received government grants for their projects in a specific year and 0 for those that did not.

3.3.2 | Green Technology transfer

This construct was measured with five items adapted from Gopalakrishnan and Santoro (2004). A sample item is “time spent interacting with university research center personnel specifically for developing and commercializing new green technologies”.

3.3.3 | Environmental commitment

We refer to environmental commitment as a firm's dedication, responsibility, and determination to operate in a manner that aligns with environmentally sustainable practices, principles, and goals (Wang et al., 2018). Accordingly, we measure environmental commitment with four items from Wang et al. (2018). A sample item is “our firm's environmental efforts receive full support from top management and staff”.

3.3.4 | Sustainable innovation

We utilized a sustainable innovation scale comprising six items adapted from Delmas and Pekovic's work (Delmas & Pekovic, 2018). Respondents were asked to assess their firms' sustainable practices from 2019 to 2021, encompassing aspects like products, processes, and organizational as well as marketing practices, all aimed at delivering environmental benefits (Adomako, 2020; Adomako & Nguyen, 2023).

3.3.5 | Control variables

We added various control variables that might impact sustainable entrepreneurship. Firm size was measured using the number of full-time employees, and firm age was assessed by the number of years the firm has been operational since its initial sales. Additionally, we accounted for industry type and CEO age, represented by the years since the CEO's birth. To measure the level of R&D activity, we utilized the logarithmic transformation of a firm's annual R&D spending. Market uncertainty was measured using three items from Jaworski and Kohli (1993), and rated on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

4 | ANALYSES

4.1 | Test for potential biases

We conducted a thorough examination to address potential biases in our study. First, we tackled non-response bias by comparing the characteristics of respondents and non-respondents within our final sample using Pearson's chi-square test for categorical data (Greenwood & Nikulin, 1996). The results revealed no significant differences in terms of firm size, firm age, and CEO age between respondents and non-respondents, mitigating concerns about non-response bias as a substantial threat to our results (Armstrong & Overton, 1977).

Second, despite the survey being completed by multiple respondents, we took measures to mitigate potential common

TABLE 1 Constructs, measurement items, and reliability and validity tests.

Item description	Factor loadings (*t*-values)
Green technology transfer: $\alpha = .88$; CR = 0.89; AVE = 0.63	
Please rate the extent to which you agree or disagree with the following statements	
Time spent interacting with university research center personnel specifically for developing and commercializing new green technologies	0.66
Level of joint decision-making in technological consulting arrangements for developing and commercializing new green technologies	0.78
Level of joint decision-making in developing and commercializing new green technologies	0.82
Level of participation in research center extension services specifically for developing and commercializing new green technologies	0.85
Number of personnel exchanges specifically for developing and commercializing new green technologies	0.87
Environmental commitment: $\alpha = .90$; CR = 0.91; AVE = 0.72	
Please rate the extent to which you agree or disagree with the following statements	
Our firm's environmental efforts receive full support from top management and staff.	0.78
Our firm commits to reducing harmful emissions resulting from production and operations	0.85
Our firm consistently assesses the impact of business on the environment	0.87
Our firm values the natural environment as much as profits.	0.90
Market uncertainty: $\alpha = .85$; CR = 0.85; AVE = 0.65	
Customers in our industry tend to look for new products all the time	0.88
New customers tend to have product needs that are different from those of existing customers	0.77
We are witnessing demand for our products from customers who never bought from us before	0.78
Sustainable innovation: $\alpha = .90$; CR = 0.91; AVE = 0.65	
We have introduced products, processes, organizational, or marketing innovations that reduce resources and materials per unit of production.	0.76
We have introduced products, processes, organizational, or marketing innovations that reduce energy use	0.67
We have introduced products, processes, organizational, or marketing innovations that reduce carbon dioxide (CO2) production	0.80
We have introduced products, processes, organizational, or marketing innovations that replace materials with less polluting or hazardous substitutes	0.84
We have introduced products, processes, organizational, or marketing innovations that reduce soil, water, noise, or air pollution	0.86
We have introduced products, processes, organizational, or marketing innovations to recycle waste, water, or materials	0.88

Abbreviations: AVE, average variance extracted; CR, composite reliability.

method bias by following the procedure outlined by Cote and Buckley (1987). We estimated three distinct confirmatory factor analysis (CFA) models to assess this bias. First, a method-only model was estimated where all items loaded on a single factor ($\chi2$/df = 6.25; NNFI = 0.16; CFI = 0.20; RMSEA = 0.19). Second, a trait-only model was estimated, where each item loaded on its respective factor ($\chi2$/df = 1.78; NNFI = 0.92; CFI = 0.91; RMSEA = 0.04). Finally, a method and trait model, combining elements from both Model 1 and Model 2, was performed ($\chi2$/df = 1.38; NNFI = 0.90; CFI = 0.92; RMSEA = 0.05). The fit indices from these three CFA models indicated that Model 1 demonstrated poor fit in comparison to Models 2 and 3. However, both Model 2 and Model 3 displayed superior fit compared to Model 1. This leads to the conclusion that common method bias indeed presents a significant concern in our study.

4.2 | Measure reliability and validity

Before testing our hypotheses, we undertook an evaluation of the validity and reliability of the measurement scales for all multi-item constructs. In line with established research recommendations (Bagozzi & Yi, 2012), we conducted confirmatory factor analysis (CFA) and utilized approximate fit heuristics to comprehensively evaluate the model fit. Non-centrality-based metrics such as Root Mean Square Error of Approximation (RMSEA) and relative fit indices like Non-Normed Fit Index (NNFI) and Comparative Fit Index (CFI) were employed to gauge the model's fitness. The CFA estimation yielded the following model fit statistics ($\chi2$/df = 1.42; NNFI = 0.95; CFI = 0.96; RMSEA = 0.06).

As demonstrated in Table 1, the standardized factor loadings of all measurement items for each sample are statistically significant

TABLE 2 Descriptive statistics and correlations.

Variables	1	2	3	4	5	6	7	8	9
Firm size (employees)									
Firm age (years)	0.02								
CEO age	−0.10	−0.03							
R&D spending (log)	0.15*	0.09	0.03						
Market uncertainty	−0.05	−0.04	−0.03	−0.12	(0.80)				
R&D support	−0.15*	−0.06	−0.02	0.11	0.11				
Green technology transfer	0.11	0.09	0.07	0.18*	0.09	0.22**	(0.79)		
Environmental commitment	0.20**	0.15*	0.11	0.06	0.17*	0.15*	0.14*	(0.84)	
Sustainable innovation	0.22**	0.12	−0.05	0.22**	0.18*	0.29**	0.25**	0.22**	(0.80)
Mean	45.06	7.59	45.27	1.19	5.21	0.65	4.85	3.65	3.44
Standard deviation	11.60	1.20	16.18	1.05	0.84	0.46	1.12	1.42	1.46

Note: Square root of AVE in the diagonal.
*$p < .05$; **$p < .01$.

(at the 1% level). Additionally, both Cronbach's alpha and the composite reliability (CR) values for each construct surpass the recommended thresholds of 0.70 and 0.50, respectively. This affirms the internal consistency of the items used to measure the constructs (Fornell & Larcker, 1981). Furthermore, we provide evidence of discriminant validity for the measures, as the average variance extracted (AVE) for each construct exceeds the highest shared variance (HSV) observed for each pair of constructs (Table 2).

4.3 | Structural model estimation

We employed structural equation modeling (SEM) with maximum likelihood estimation using LISREL 8.80 to test a system of nested structural models. To simplify the model, we computed mean values for the dependent and moderating variables, generating composite scores for multi-item constructs. Specifically, we calculated averages for each multi-item construct to obtain composite scores. However, for the dependent variables (green technology transfer and sustainable innovation), we utilized the full information approach, employing the individual measurement items instead of mean values for model estimation. This dual approach of using averages and the full information method helped address potential model under-identification issues resulting from inadequate information in the structural model (see Adomako et al., 2022; Hair Jr et al., 2017). Following established practices (e.g., Cortina et al., 2001), we utilized moderated structural equation modeling to assess the hypothesized moderation relationships. Consequently, for our moderator (environmental commitment), we created one moderating term: (1) green technology transfer X environmental commitment. To mitigate multicollinearity concerns, the constructs used to generate the moderation term were mean-centered before computing their cross-products.

In total, we tested five models sequentially. Model 1 had green technology transfer as the dependent variable, while models 2–5 had sustainable innovation as the dependent variable. In Model 1, we estimated the effects of R&D support on green technology transfer. In Model 2, we tested the direct effects of R&D support on sustainable innovation. Model 3 incorporated the effects of green technology transfer and the moderating variable (environmental commitment). In Model 4, the interaction effect variable, (green technology transfer X environmental commitment) was added to the equation. Finally, following recent mediation estimation procedures (e.g., Adomako et al., 2022), we estimated Model 5, the full structural model using the single model estimation procedure where both green technology transfer and sustainable innovation served as dependent variables. This SEM estimation procedure allowed us to simultaneously evaluate both paths. Following each model estimation, we reported model fit indices and variations in squared multiple correlations (R^2) where applicable.

4.4 | Results

H1 proposed a positive association between R&D support and green technology transfer. The results of model estimation, as presented in Table 3, affirm Hypothesis 1 ($\beta = .21$; $t = 3.30$; $p < .01$). H2 states that green technology transfer mediates the relationship between R&D support and sustainable innovation. We find support for Hypothesis 2. Specifically, the model estimates reveal a positive relationship between R&D support and sustainable innovation ($\beta = .19$; $t = 2.99$; $p < .01$) and green technology transfer ($\beta = .21$; $t = 3.30$; $p < .01$). Additionally, a positive relationship is observed between green technology transfer and sustainable innovation ($\beta = .14$; $t = 2.44$; $p < .05$). These observations suggest that green technology transfer mediates the relationship between R&D support and sustainable innovation.

To confirm the mediation hypothesis (H2), we followed the approach by Hayes and Preacher (2010), we conducted the Sobel test and utilized bootstrapping to determine the significance of the indirect effect. As presented in Table 4, the results indicated a significant

TABLE 3 Results of structural model estimation.

	Independent variables dependent variables					
	Green technology transfer	Sustainable innovation			Green technology transfer	Sustainable innovation
	Model 1	Model 2	Model 3	Model 4	Model 5	
Control paths						
Firm size	0.11 (1.04)	0.21 (3.49)**	0.18 (3.39)**	0.16 (2.37)*	0.09 (1.11)	0.14 (2.38)**
CEO age	0.06 (0.48)	−0.03 (−0.47)	−0.04 (−0.61)	−0.05 (−0.44)	0.03 (0.40)	−0.03 (−0.41)
Firm age	0.08 (0.45)	0.09 (1.46)	0.06 (0.58)	0.05 (0.80)	0.04 (0.28)	0.08 (0.89)
R&D spending (log)	0.15 (2.89)**	0.20 (3.40)**	0.17 (2.69)**	0.16 (2.70)**	0.14 (2.94)**	0.17 (2.70)**
Market uncertainty	0.08 (0.50)	0.17 (2.63)*	0.15 (1.99)*	0.13 (1.89)	0.10 (0.59)	0.14 (1.98)*
Direct effect paths						
R&D support	0.21 (3.30)**	0.19 (2.99)**	0.16 (2.79)**	0.17 (2.98)**	0.20 (3.19)**	0.13 (1.49)
Green technology transfer (GTT)			0.14 (2.44)*	0.15 (2.88)**		0.14 (2.24)**
Environmental commitment (EC)				0.20 (3.71)**		0.12 (1.74)
Two-way interaction path						
GTT * EC				0.29 (4.19)**		0.28 (4.12)**
Goodness of fit indices						
R^2	0.22	0.15	0.19	0.24	0.30	
ΔR^2	–	–	0.04	0.05	0.05	
χ^2/df	1.58	1.30	1.42	1.42	1.89	
CFI	0.92	0.94	0.95	0.95	0.91	
NNFI	0.91	0.93	0.93	0.92	0.90	
RMSEA	0.04	0.05	0.04	0.05	0.04	

Note: Critical values of the t distribution for $\alpha = .05$ and $\alpha = .01$ (two-tailed test) are * = 1.96, and ** = 2.58, respectively (*t*-values are reported in parentheses).

TABLE 4 Indirect effect and significance using the normal distribution.

	Value	SE	z	*p*
Sobel	0.05	0.02	2.15	.05
	Effect	**SE**	**LL 95% CI**	**UL 95% CI**
Bootstrap results for the indirect effect	0.03	0.02	0.03	0.13

Note: N = 220. Bootstrap sample size = 10,000.
*$p < .05$; **$p < .01$.

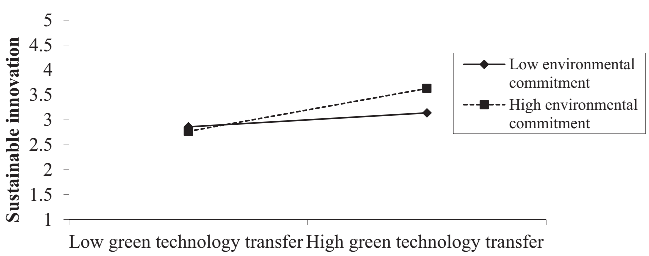

FIGURE 1 Interaction of green technology transfer and environmental commitment on sustainable innovation.

indirect effect (Sobel z = 2.15, *p* = .05). This finding was further confirmed using the bootstrapping method. We proceeded to estimate 95% bias-corrected confidence intervals (CI) for the indirect effect by bootstrapping 10,000 samples. The results from the bias-corrected CI ranged from 0.03 to 0.13, with zero excluded from the CI. Given the absence of zero within the CI, we concluded that the indirect effect significantly deviates from zero (Shrout & Bolger, 2002). Thus, H2 received support.

The second part of the analysis investigates the moderating effect of environmental commitment on the relationship between green technology transfer and sustainable innovation. As illustrated in Table 3, we find evidence supporting H3, indicating that the effect of green technology transfer on sustainable innovation is enhanced by environmental commitment ($\beta = .29$; $t = 4.19$; $p < .01$). To explore the direction of the moderation, we followed the recommended procedure (Aiken & West, 1991) and generated a graph illustrating the moderation at one standard deviation above and below the mean of environmental commitment (see Figure 1). The results obtained from the simple slope analysis revealed that the impact of inter-organizational collaboration on technology transfer intensity was more pronounced when environmental commitment was high (simple slope = 0.31, $t = 3.69$, $p < .01$). Conversely, the slope was notably weaker when environmental commitment was low (simple slope = −0.03, $t = -0.09$, $p > .10$).

5 | DISCUSSION AND CONCLUSION

Deriving insights from the RBT (Barney, 1991; Barney et al., 2001), we investigated the impact of R&D support on sustainable innovation through the mediating role of green technology transfer. Additionally, we explore the moderating effect of commitment to environmental ethics. Our results show that providing support for R&D positively influences the transfer of green technology and the transfer of green technology acts as a mediator in the link between R&D support and sustainable innovation. Finally, our results revealed that the impact of green technology transfer on sustainable innovation is amplified when a firm is dedicated to upholding environmental ethics. These findings offer several theoretical and practical implications to the literature.

5.1 | Theoretical implications

First, we expand the sustainable innovation literature (e.g., Adomako, 2020; Adomako & Nguyen, 2023; Cillo et al., 2019) by explaining the role of government R&D support. Previous studies have shown that sustainable innovation is driven by several factors such as environmental ethics (Rui & Lu, 2021), regulatory innovation policy (Foxon & Pearson, 2008), and collaborations (Reficco et al., 2018). While previous research has improved our understanding of the drivers of a firm's sustainable innovation strategy, we lack a solid understanding of the role of R&D support from the government and the mechanism through which R&D support in the form of funding relates to sustainable innovation. In this study, we show that the degree of green technology transfer serves as a mechanism of this relationship. In doing so, we add to the sustainable innovation literature by clarifying the path through which R&D support yields sustainable innovation.

Second, our findings advance our understanding of a boundary condition, shedding light on when green technology transfer impacts sustainable innovation. In particular, we show that commitment to environmental ethics is such a boundary condition in the relationship between green technology transfer and sustainable innovation. Consequently, our findings contribute meaningfully to ongoing dialogs within the sustainable innovation literature (Boons et al., 2013; Larson, 2000; Reficco et al., 2018). In essence, this insight highlights the necessity of a specific threshold of environmental commitment for green technology transfer to effectively facilitate the translation of green technology transfer into sustainable innovation outcomes, particularly within emerging economies.

Finally, our findings show that R&D support predicts green technology transfer. Through this finding, we add to the green technology transfer literature (Fu & Zhang, 2011; Hall & Helmers, 2010; Jiang et al., 2023; Orsatti, 2023). Exploration of the factors influencing green technology transfer among firms in emerging economies, especially in Vietnam, is notably lacking in research. The existing emphasis on green technology transfer within developed economies raises concerns about the applicability of Western theories and discoveries in the context of developing and emerging economies. Consequently, our study introduces fresh perspectives on how R&D support from the government assists firms in emerging markets in advancing green technology transfer. This stands as a significant expansion of green technology literature since prior research has not explicitly delved into this matter within emerging and developing economies.

5.2 | Practical implications

This study holds practical value. The results offer insights for managers seeking to enhance their firms' sustainable innovation performance by leveraging R&D support within green technology transfer. In an era where an increasing number of firms are embracing sustainable innovation (Boons et al., 2013; Hellström, 2007), understanding the impact of R&D support on sustainable innovation is crucial for managers. The findings also assist in identifying areas ripe for sustainable innovation enhancements. By examining the relationship between R&D support and sustainable innovation, managers can pinpoint where additional R&D support or investments could yield benefits (Sarpong et al., 2023; Yao & Huang, 2022). This knowledge equips managers to adeptly navigate technology adoption within their organizations and effectively tap into external knowledge and technology. Moreover, recognizing that green technology transfer positively influences sustainable innovation is important for the strategic management of intellectual property portfolios. Given that technology transfer often involves sharing intellectual property (Siegel et al., 2023; Suh & Oh, 2015), a sensitive matter, managers can devise strategies for managing intellectual property through R&D support. Finally, the findings from this research can inform the development of a targeted technology transfer strategy. Managers can utilize this information to ascertain the most effective types of government R&D support, the facilitating factors for technology transfer, and the optimal practices for intellectual property management.

5.3 | Limitations and future research

Despite the rigorous methodology employed in our study, which involved data collection from separate sources for the dependent and independent variables to mitigate spurious correlations (Podsakoff et al., 2012), certain limitations present opportunities for future research. First, although we collected time-lagged data to establish temporal relationships between the variables, we couldn't establish causality due to the lack of variable manipulation or randomly assigned techniques. Future research can address this by adopting a longitudinal design spanning multiple years. Second, our use of subjective measures for capturing sustainable innovation raises the possibility of bias in the perceptual measures collected from individual managers. Future research could alleviate this concern by incorporating objective data collection methods where feasible. Third, we did not delve into how CEOs' characteristics influence SMEs' sustainable innovation. Characteristics such as CEOs' hubris could be particularly detrimental to SMEs in emerging economies. Future research could explore how CEOs' characteristics, like narcissism and overconfidence, affect the relationship between firms' sustainable innovation strategies in diverse contexts. Fourth, our study focused on a single country (Vietnam), limiting the generalizability of the findings. Future investigations could extend to other country settings, considering unique contextual idiosyncrasies. Additionally, a multi-country study design could further enhance understanding and contribute to the sustainability literature. Finally, our study focused on well-established SMEs, possibly restricting the generalizability of our findings. Future research could broaden these findings by examining other types of firms, such as early-stage ventures and non-SMEs.

In conclusion, our study delved into the impact of R&D support on sustainable innovation through green technology transfer. We also explored the moderating effects of environmental commitment on the relationship between green technology transfer and sustainable innovation. Our findings contribute to the growing sustainability and innovation literature in emerging markets and provide practical implications for managers. We aspire for our research to inspire scholars to build upon the discoveries in this study.

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